TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

Page

Presidential Address: Lighting and Electricity Supply, by E. C. Lennox, M.I.E.E. *(Fellow)* - - - - 1

Additions to the List of Members - - 14

Lighting and Visibility in Mines, by A. Roberts, M.Sc., Ph.D., A.M.I.Min.E., A.M.I.M.M., A.M.Inst.C.E. *(Member)* - - 15

Home Lighting, by Arthur H. Young, A.M.I.E.E. *(Member)*, and C. J. Misselbrook, B.Sc. (Eng.) *(Fellow)* - - - 37

VOLUME XX
No. 1 — 1955

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

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Presidential Address

Lighting and Electricity Supply

By E. C. LENNOX, M.I.E.E. *(Fellow).*

May I first express my sincere thanks for the great honour you have conveyed in inviting me to be your President for the forthcoming year. I follow a line of distinguished men, many—as in the case of our immediate Past President—scientists engaged in research. To be the first engineer from the electricity supply industry to be accorded this signal honour is a tribute to that industry which now provides energy for all but the smallest part of the nation's artificial lighting.

It was Michael Faraday in 1831 who, by his crowning discovery of electro magnetic induction, prepared the way for the development of the electric dynamo and transformer which were to become the basis of the electricity supply industry. My interest in the industry has extended over forty years and to be able to present this address at the Royal Institution which was for so long the home and workshop of Michael Faraday is, I feel, another great honour.

Historical

In the first part of this address I should like to deal briefly with the development of electricity supply, with special reference to the development of artificial lighting.

The year 1880 was just before the advent of public electricity supply. At this date the wax candle and oil burning were in general use; gas was in fair supply as a means of lighting but relied entirely on the luminosity of the gas flame, making use of burners such as the fish-tail type (the incandescent mantle which was to be the electric lamp's greatest competitor did not arrive until some thirteen years later); electric lighting as such was confined to various forms of electric carbon arc.

In 1870 Gramme had produced his dynamo with ring wound armature, and in 1880 there were several hundred electric dynamos in service driven by steam engines supplying various designs of electric arc lamps. The popular lamp of the day had been produced in 1876 by Paul Jablochkoff, named after him the Jablochkoff Candle. In this lamp carbons were fixed in pairs in holders so connected as to allow a current to pass up one carbon, jump across the gap and down the adjacent carbon producing an arc at the top. The lanterns were usually in chandelier form with ground glass globes fitted with several pairs of carbons so arranged that as one pair was used up another was connected, each pair lasting a matter of 1½ hours.

In 1877 the general view in regard to a public electricity supply was probably as expressed by the Surveyor of the Vestry of Chelsea who had seen these lamps installed in Paris and was reporting on their use for public lighting in London. His report showed improved values in illumination without evidence of decreased costs. The advantages he claimed over existing gas lighting included—" a saving of time in lighting and extinguishing "—" a vastly improved lighting to gas (fishtail flame burners) "—" not injurious "—" absence of noxious smells both in production and consumption "—" most delicate colours are preserved "—" air is not consumed "—" no chance of explosion "—" although the light is so powerful no accidents to horses have occurred." He was disappointed with the fact that one electrical machine would only light sixteen lanterns and decided that " the present arrangements of electric lighting were unsuitable for long distances and that the close proximity of the electric lighting stations in business streets would be a matter of great difficulty." He brought out the need for " sub-division of the light " and the " means of working over greater distances." Nevertheless these lighting units were introduced for public lighting on the Holborn

Presented at a meeting of the Society held in London, October 12, 1954.

Viaduct and on the Victoria Embankment, the latter installation operating quite successfully for some years.

Legislation

Up to this date (1880) there had been no real incentive to develop a supply distribution system common to both public street lamps and private premises. The use of electric lighting inside buildings, and especially in domestic premises, only became an attractive proposition when, following the inventions of Swan (1878) and Edison, the employment of incandescent lamps in parallel on supply circuits became possible.

Even so, it is interesting to record the doubts expressed at that time of the value of the Swan/Edison incandescent lamp. Professor Sylvanus P. Thompson at Bristol in the couse of a lecture on the "electric light," December 8, 1878, said: "I cannot tell you what Mr. Edison's particular method of distributing the current to the spirals may be, but this I can tell you as a result of all experience, that any system of lighting by incandescence will utterly fail from an economical point of view and will be the more uneconomical the more it is sub-divided." Professor Thompson lived to know different and became in 1909 the first President of this Society.

Prominent engineers who appeared at the subsequent Parliamentary enquiry into the problem of legislation concerning the distribution of electrical energy also failed to make direct reference to the new form of lighting. Fortunately other engineers including Edison, saw the need for public supply from central generating stations, in the same way as for gas and water, and the need for legislation to assist in that development by giving powers for the breaking up of streets.

The first electricity act—Electric Lighting Act 1882—as the name implies, gave emphasis to the prime need for supply, namely to supply electricity for lighting purposes, but development under the Act was negligible. At this time Sir Joseph Chamberlain was President of the Board of Trade and he was strongly in favour of municipal control. Under such influence the Act contained the right of purchase of the undertakings by the local authorities at the end of 21 years. This purchase was to be at the depreciated value of the capital, without any addition for goodwill, or for present or future profits. Under such a scheme financial development by the public was shunned and for six years public supply remained in a moribund condition.

In 1888 it was stated in Parliament that 50 provisional orders and two licences to companies had been granted since the passing of the 1882 Act and that the Board of Trade were "not aware of any cases in which powers obtained were now being exercised." Such companies as were operating did so without the benefits of the Act, and to avoid the breaking up of streets were distributing electricity by means of overhead lines. The distribution of electricity in this country, therefore got off to a very bad start.

The 1888 Act increased the period of right of purchase by local authorities from 21 to 42 years; investment in the industry thereby became a better financial proposition and from this date supply of electricity began to move forward.

Early Distribution

The introduction of the carbon filament lamp was the basis for the first public supply of electricity. Operation of street lamps in series, using separate electric cables, was no longer necessary. The distribution systems were laid out in pairs of wires from busbars in the supply stations to consumers and street lamps alike. The original system was at 110 volts which was only economical for distribution over short distances.

The three-wire distribution system introduced by Dr. Hopkinson (1882) enabled supply to be sent out at 220 volts without increasing the 110 volt supply for the lighting and thereby not increasing electrical danger in consumers' premises. The benefit of the longer distribution (1¼ times the distance for equal weight in copper and equal percentage

in distribution loss) was obvious. Dynamos were constructed to supply full voltage for the overall pressure, smaller dynamos being introduced to run in series and supply out of balance energy between outer and neutral.

There was considerable discussion over the relative advantages of direct current and alternating current. Edison was one who advocated direct current, having in mind the use of electricity for small direct current motors and the advantages of incorporating a stand-by electric battery at the supply station. Ferranti, among others, recognised the limits of transmission distances by direct current and in 1885 was prepared to supply energy at 2,500 volts alternating current with transformers at required points working with their primary coils in parallel, secondary windings producing 220/110 volts to supply the ordinary glow lamps of the day. The new system required small conductors for the high voltage feeders (overhead lines) and enabled distribution of electricity to be spread over greater distances from supply stations. But Ferranti met with considerable difficulties and for some time his scheme had limited application.

Typical load curves showed that the maximum demand was between six and eight p.m. on a winter evening, the plant being relatively idle for the remaining hours of the day. In 1891 Crompton first used the term "load factor" which may be said to be the ratio of the units sent out in a year related to the total which would be sent out if the load level of maximum demand had been maintained throughout the year. The higher the load factor the more economical the supply problem. To maintain plant which was relatively idle during long hours out of the 24 was obviously uneconomic. In residential areas the average annual load factor was seldom more than 10 per cent.

By 1893 electric lighting was being developed rapidly. The maximum lamp voltage was still 110, and whereas there was a multiplicity of arc lamps giving 20 lumens per watt, carbon filament lamps gave only 2/3 lumens per watt.

There was considerable trouble over the granting of provisional orders, "promoters" obtaining these orders merely for reselling at financial gain. Mr. Preece in his presidential address to the I.E.E. in 1893 declared that public distribution in England had been retarded by the "limited liability legislation and by rapacious financial promoters whose plunder in one year far exceeds that in amount of the sum of all the thefts of all highwaymen and burglars ever hanged—and which ruined private enterprise." He was also concerned with the price of lamps stating that "glow lamps which were being sold in 1882 at 25s. were being sold in 1893 at 3s. 9d. each but they cost only 9½d. to make and should have been sold at 1s. The high cost of wiring was a great deterrent. Generally it was being carried out in wood casing, V.I.R. insulating cables, but the absence of a specification was generally felt." Even at this date, the activities of the "cheap-jack" electrician were described as a curse.

The need for development in the lighting of public streets was appreciated. It was stated that "accidents in large towns were relatively greater during the hours of darkness than during daylight," a statement of fact which remains unchanged at the present time.

That there was confidence on the part of the engineers may be seen in the fact that fears were expressed for the gas companies of the day and it was stated that the gas industry "should have nursed this herculean infant who was strangling its main source of profit." But with the introduction of the incandescent mantle the struggle for the business of supply of artificial light was to last for many years to the credit of both undertakings and to their eventual profit.

Swan described electric lighting as "the poor man's light," and said that "nothing could stop its growth" but the long-hour use of the full output of the stations was still a dream. Loads being still mainly that of lighting, load factors were still very low. A combined curve for the Central London Stations taken over a period of 24 hours showed a load factor of 15 per cent., and it was calculated that if the

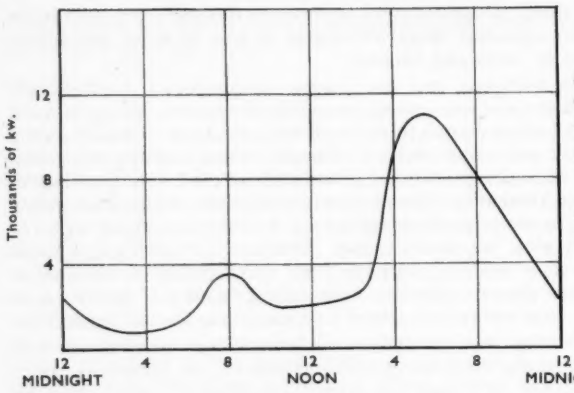

Fig. 1. Load curve for London area (all stations) Dec. 20, 1894.

Max. load 11,600 kw. at 5.30 p.m.

Min. load 800 kw. at 4.0 a.m.

Load factor 33 per cent. for day, 15 per cent. for year.

average load factor could be raised from 15 to 30 per cent., the cost per unit could be halved. In certain cases the efficiency of stations was increased by closing down between the hours of 8.30 a.m. and 2 p.m. each day.

Such were the problems of 1893-94, when the use of energy for other than lighting purposes was being developed. A strange reflection of the early development for other purposes may be observed by a quotation from Crompton in his presidential address to the I.E.E. (1895), when he impressed upon the industry the need for improving load factor, and indicated—"it is easier to educate the public in the use of heating and cooking appliances than to induce them to use motive power to any extent."

The development in 1896 of the 220-volt carbon filament lamp was taken as a golden opportunity by the supply industry to cut distribution costs by developing mains at double the pressures previously used. With double the pressure energy could be supplied to meet the needs of four times the lighting with the same mains, or the same lighting over four times the distance. The 220-volt lamps, however, were less efficient; to overcome the decreased efficiency some undertakings offered a reduction in the price per unit. It was argued that consumers using 110 volts and paying sixpence per unit with lamps at 2.7 watts per candle received similar value to 220-volt consumers paying fourpence per unit with lamps at 4 watts per candle. Fortunately the efficiency of 220-volt lamps improved, and such differentiation was eliminated. In the United States there are still many areas with 110-volt distribution, and indeed considerable lighting installations with lamps connected for series burning. In this country we aim to standardise our supply voltage at 240, and have developed considerable low-voltage networks on a three-phase four-wire basis, giving 415 volts between any two of the three phases and 240 volts between phase and neutral.

Nineteen hundred and six was a year which greatly affected the relationship of electric lighting and electricity supply. In this year there were less than 1,000 M.W. of generating plant, with an average load factor of less than 14.5 per cent. The units sold were only 530,000,000 per annum (a considerable proportion of which was for lighting purposes) supplied from a multiplicity of generating stations scattered throughout the country. Supply was distributed mainly in restricted areas, each undertaking following its own economic policy of independent development.

At this date the tantalum lamp was introduced with its considerably improved efficiency of 6/7 lumens per watt and, later, the tungsten filament lamp with an even better life and light output of 7½ lumens per watt.

To the illuminating engineer of to-day such development would spell hopes of

better lighting, but to supply engineers of 1906-10 it meant a considerable drop in the revenue from the majority of their consumers. Records show that in 1909 the average 8-candle-power carbon lamp (33 watt) was being replaced by the 14-candle-power metal-filament lamp (16 watt). The effect of this on a supply undertaking's revenue can be readily imagined. It is true that the greater efficiency brought additional consumers, but they were largely consumers of the "short-hour" type. It is said that 18 per cent. of the consumers of that time were using lighting for an average of only one hour per day, producing a revenue, based on 100-watt average use, of 15s., and on 50-watt average use of only 7s. 6d. per year (fivepence per unit). These consumers were costing more to meet their demand than they paid, and they were present in relatively large numbers.

To attract the "long-hour" user and to increase the charges to the "short-hour" user, there were suggestions that consumers should pay a fixed charge based on maximum demand tariffs inclusive of estimated consumption. New tariffs for domestic consumers included a fixed charge related to the cost of meeting the electrical demand, and based on such items as rateable value, number or capacity of lamps installed, plus a small unit rate.

To attract domestic consumers, undertakings offered schemes of "free wiring" and, for an "all-in" weekly charge, provided capital cost of electricity service, wiring, limited number of lamps per annum, and electricity. These charges obviated the need for meters and saved the cost of meter reading and accountancy. This system, for

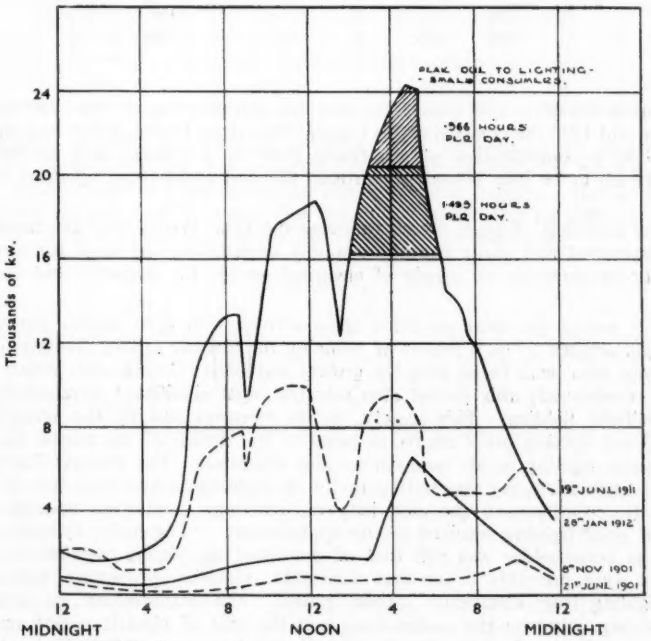

Fig. 2. Load curves 1901 and 1911
Summer - - - - -
Winter ———

the time being, turned otherwise uneconomical consumers into profitable consumers, but some 10 to 15 years later the consumption for lighting had been so exceeded by the consumers' use of other domestic appliances that it became advisable to instal metering and apply normal tariffs.

This period (1909) also saw the inauguration of the Illuminating Engineering Society, and no doubt from this time the benefits to be obtained from improved lighting were brought more forcibly to the notice of the public.

The 1914-18 war saw an immense increase in the load taken from supply-authority mains for power purposes. The induction motor had proved its worth; works and munition factories called for unlimited power and for the first time revenue from power greatly exceeded that of lighting. Power-station generating plant and units supplied increased.

Table 1

Year	Great Britain	
	Plant Installed (M.W. thousands)	Units Sold (Millions)
1906	1	500
1913	1¾	2,000
1920	2½	3,660
1926	5	5,600

Nineteen hundred and twenty-one saw the introduction of the Electricity Commissioners and 1926 the creation of the Central Electricity Board, which was empowered to undertake a concentration of generating plant in a selected and limited number of stations, all to be inter-connected through the grid system and operated under one control.

In the recession of trade which followed the First World War the revenue from power diminished and made urgent to supply undertakers the need for attention to the further development of supply of electrical energy for domestic and commercial purposes.

In this period the clear gas-filled lamp arrived with 8/10 lumens per watt, and at first sight seemed to be a means of reducing the already falling revenues of supply undertakings who were faced with the greatly increased running costs which followed the war. Fortunately this period also saw the most significant development in the use of artificial lighting. This society, by its meetings and by the activities of its members, was making great efforts to bring to the notice of the public the dangers of inadequate lighting in all occupations and situations. The Electric Lamp Manufacturers' Association, by the setting up of its lighting service bureaux in different parts of the country, and the electricity undertakings themselves ensured that the benefits of good lighting received public appreciation. The main difficulty affecting the average householder was still that of providing the wiring installation. At this time there were probably fewer than 1,500,000 domestic properties supplied with electric lighting from electricity supply mains. The introduction of schemes of assisted wiring, whereby the undertaking met the cost of electric wiring on a long-term hire, or hire-purchase basis, brought this total to over 10,000,000 by 1939.

The introduction of yet more efficient lamps, including the coiled coil metal filament lamp with its efficiency of up to 14 lumens per watt, and the electric discharge

lamps of up to 45 lumens per watt, no longer instilled fears of reduced revenues, but were welcomed by supply authorities as means of increasing the use of electricity.

Nationalisation of the electricity supply industry under the Electricity Act, 1947, has brought further benefits in the generation and distribution of electricity on a nation-wide basis. This Act brought together 578 municipal and private undertakings, allotting to the Central Authority of the British Electricity Authority the problem of generation and to the 14 Area Boards the responsibility of distributing the energy to the public. (The north-east coast—now covered by one Board—was formerly supplied by 31 undertakings with 31 different policies.) To the Central Authority fell the responsibility of providing adequate generating plant to meet the nation's need. And similarly to the Electricity Boards the need for reinforcing and extending the distribution systems to meet the increased demands being made upon them, which may be appreciated from the greatly increased consumption during the years 1938-1950.

Table 2

Load	Units Consumed (Millions)		Percentage Increase
	1938	1950	
Domestic	5,240	13,458	157
Commercial	3,127	5,444	74
Industrial	11,180	22,217	100
Public lighting	363	360	—
Total:	19,910	41,479	108

A further problem was that of levelling tariffs throughout the country. The multiplicity of ideas of the 578 undertakings had to be replaced by tariffs with a common basis. There is available to-day throughout the country a standard tariff for lighting purposes and, in many cases also, the energy is available for lighting at charges common to those for other commercial, industrial or domestic uses.

Table 3

Electricity sales and revenue (total)				Estimate for lighting only				
				Consumption				
Year 1952/3	Units (millions)	Revenue £ (millions)	Av. price per unit (pence)	Percentage	Units (millions)	Revenue £ (millions)	Percentage	Av. price per unit (pence)
Domestic	16,201	98	1.45	20	3,200	40	41	3.0
Commercial (farms)	8,287	61.5	1.83	60	5,000	41.5	67	2.0
Industrial (tract.)	27,279	123.25	1.09	10	2,703	19.75	16	1.75
Public lighting	497	2.75	1.34	100	497	2.75	100	1.34
Totals:	52,264	285.5	1.31	22	11,400	104	36	2.2

Based on the average efficiency for the year 1952/53 of all power stations in the country (B.E.A. Annual Report 1952/53), this energy represents a consumption of coal of 7.5 million tons, or 3 per cent. of the national coal output.

Electric Lighting and Fuel Economy

As electricity is sold to the majority of consumers at an "all-in" rate for all purposes there is little separate data as to the actual consumption for lighting purposes. The figures indicated in Table 3, based on the British Electricity Authority's fifth report and accounts 1952-53, are a reasonable estimate showing the value of the present lighting consumption.

The coal used in modern power stations is made up of 90 per cent. "smalls" and "slurry," it is generally unsaleable except for use in the most efficient of boiler plants, and has an average calorific value of only 10,948 B.Th.U's per 1 lb. weight compared with between 13,000/14,000 B.Th.U's for coal used by other large users. Yet with such low thermal value the conversion factor of coal to lumens is improving each year with the introduction of new power station plant. Average overall thermal efficiencies of power station plant have improved from 20.87 per cent. in 1947 to 22.72 per cent. in 1952/53.

Table 4

Lumen hours per 1-lb. coal

Type of lamp	Lumen hours
Incandescent gas light	3,960
Tungsten	9,500
Mercury Vapour	24,000
Sodium Vapour	37,700
Fluorescent	29,000

Based on an average power station efficiency of 22.72 per cent.

It is interesting to note that the newest power stations have reached efficiencies of over 30 per cent. and that by 1960 the average overall thermal efficiency of the power stations may well be 26 per cent. There is, therefore, no need to allow questions of fuel shortage to mar our future outlook of increased illumination for all purposes. The certain promise of the use of atomic energy to provide heat for future power stations still further enhances the economic outlook of the use of electricity for lighting and other purposes.

Utilisation

In a little over half a century electricity has taken upon itself the duty of providing all but a small part of the nation's artificial lighting. The lighting value received for 1d. in lumen hours has increased from a figure of 440 in 1893 with the use of the carbon filament lamp, to that of 23,000 in 1954 making use of the modern fluorescent lamp. This is the result of the efforts of both the electric lamp manufacturers and the supply industry.

Such progress in efficiency, when related to other amenities, should be an inspiration to all concerned in these industries. Can we be equally satisfied with the use which is being made of this wonderful achievement? Have we been so successful in the use of the benevolent possibilities of improved lighting as we appear to be in other spheres?

In the Home

For centuries winter was a dreaded period of half living, of gloom, of flickering shadows, and of reduced achievement. Electric lighting has given simplicity and flexibility. It can be used as a decoration, or to enhance decorations. Alongside the

Table 5

Value of Lighting Received: Lumens per Penny—1893/1953

Year	Type of lamp	Watts	Lamp life (hours)	List price of lamp	Cost of electricity per unit	Cost of electricity plus lamp	Lumen hours per penny	Cost of living (comparison)
				pence	pence	pence		
1893	16 C.P. Carbon 100-volt	64	800	45	8	455	440	—
1910	Tantalum 230-volt	60	800	30	5	270	1,060	—
1914	Clear Vac.	60	800	30	5.75	306	1,120	100
1924	Clear G.F. (Single coil)	60	1,000	36	4.2	288	1,620	160
1934	Pearl single coil	60	1,000	22	2.13	150	3,500	149
1939	Pearl coiled coil	60	1,000	19	1.6†	115	5,500	152
1954	Fluorescent new warm white	95	5,000	193*	1.5†	905	23,000	300

*With purchase tax.

†Domestic Tariff:

Primary units ... 4d.
Secondary ,, ... 2d. } 76 per cent. of consumers on domestic tariff receive energy at ½d. per unit.
All over ,, ... ½d.

revenue it has produced has developed the multitude of electrical appliances now available in the home. Notwithstanding, lighting is still the paramount electrical service in the home. Unfortunately, the simplicity of electric lighting has been a mixed blessing and the revolution of the past years has gone little further in millions of homes than the introduction of convenient switches and naked lamps. Of the 12,500,000 homes now wired, not more than 10 per cent. can be considered well lighted by modern standards.

Even to-day, too small a percentage of new homes and existing houses, now being wired for the first time, are having electrical installations provided in accordance with the approved recommendations which allow for a reasonable number of socket outlets in all living rooms—"Lighting of Buildings" (Post-War Studies No. 12): British Standards Institution Code of Practice 324/101/1948—Provision of Electric Lighting in Dwellings. The great appetite for light which is shown in this country by our love of sunshine cannot be said to have been seriously exploited. Bedrooms still have the conventional ceiling pendant in front of the window; a bed-head light and sensible dressing table lighting are rarely provided. Kitchens and living rooms generally still have a single pendant. The great variety of lighting effects, the subtlety of side lighting, and the potentialities of fluorescent lighting are all submerged in an indifference which pervades not only the electrical industry but apparently also the building trade and architectural profession.

Although from 1910 to date there has probably been an average increase in the number of hours use of artificial lighting in the home from, say, 1,000 hours to 1,500 hours per annum, there has been little advance in the average wattage of lamp used,

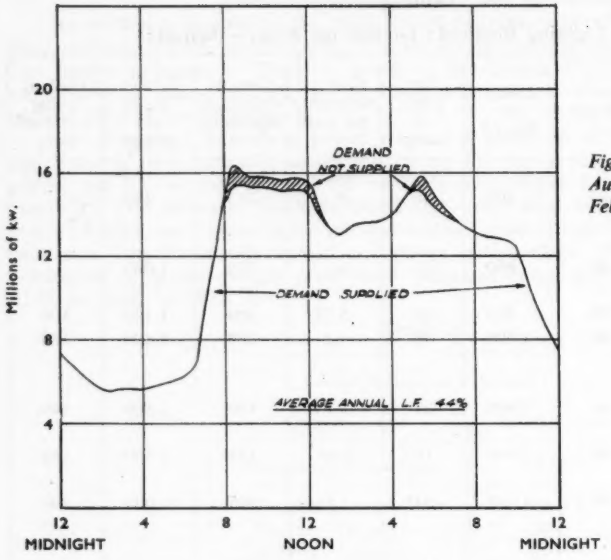

Fig. 3. British Electricity Authority system demand, February 2, 1954.

and 60-watt lamps are still common in living rooms providing less than 4 lumens per square foot.

The amount spent by the weekly wage earner in lamps and electricity for lighting purposes remains practically the same to-day as in 1910 (approximately 35s. per annum). The percentage expenditure in respect to annual earnings has dropped from 4d. to 1d. per £1 of wages. There is no service the weekly wage-earner can purchase for his house which will give better value to his household than to double the illumination. Using higher wattage, more efficient lamps and electricity at the lower rate, he can buy this additional lighting for the sum of 10s. per annum—an increase of about ¼d. per £ of his average wages.

Home lighting in the twentieth century is like a transformation scene on which the curtain has come down too soon. No longer does the average sales assistant in an electricity service centre look upon the electric lamp as an important sale. He is too occupied with the sale of electrical apparatus which brings an apparently larger return. Should he be asked for a 60-watt lamp he provides a 60-watt lamp, but consideration of the problem from a sales angle would show that the selling of a 100-watt lamp for the benefit of improved lighting would bring an additional consumption of some 60 units per annum against, say, a vacuum cleaner with a consumption of only 5-10 units per annum. No doubt the vacuum cleaner has its place in the home in its labour-saving appeal and its hygienic value, but the increased lamp sale would bring light of increased standard no less important to the customer and his family. There is room for a revival of the energy displayed in the pre-war period to bring the advantages of better lighting to the notice of the small consumer.

Members of this Society are well satisfied with the value of good and efficient lighting fittings. Can they be equally satisfied that such fittings are available to the weekly wage earner at prices he can afford?

In Industry

Electric lighting is now regarded as a positive adjunct to production as well as an important factor in workers' welfare. Official recognition in the 1937 Factories Act of six lumens per square foot over working areas, whilst being modest, represented a great improvement in official thinking.

Investigations of the importance of lighting to productivity have shown that the function of lighting in production is not only to improve visual performance but also to affect production, more especially by improving the quality of the work produced. Fluorescent lighting has rapidly become established as the desired form of factory lighting; where it is used illumination levels have improved and artificial lighting has become superior to the interior natural lighting earlier in the working day.

The effect of this improved lighting in the reduction of accidents is an item difficult to measure but undoubtedly of great financial and human importance. Yet there are still many works and factories where no attempt has yet been made to take advantage of modern illumination. It is stated that the average load factor of industrial power supplied by the electricity industry is only 30 per cent. Improved lighting makes possible, with efficiency, the operation of industrial establishments over a greater proportion of the 24 hours than are being used to-day, an extension which would bring increased prosperity to the nation by the increased output per £1 of capital outlay, of industrial premises, of plant, of national transport, and of electricity power stations.

Once installed, great importance should be attached to the regular and efficient maintenance of an improved installation. The question arises as to whether electricity boards, or electrical contractors who already have departments for maintenance of street lighting, should undertake the maintenance of large lighting installations? Such maintenance would produce an unseen revenue to electricity boards in making good the loss of wattage of the installation due to lamps burning beyond their normal rating.

In Commercial Premises

Fluorescent lighting has revolutionised the lighting of shops and stores to an extent which is difficult to detail. Progressive shopkeepers realise that their windows cease to be of value unless properly illuminated. In shops, as also in offices, the value of artificial lighting as a supplement to daylight means that in up-to-date commercial premises there is probably now more electric lighting used during daylight than after dark.

Generally speaking the benefits of improved lighting in business premises are available at a cost less than the additional value obtained by the better use of the premises themselves. Is it not therefore a matter for regret that so many shops and offices have failed to take advantage of these benefits?

Architecture

Perhaps the greatest potential value of the new form of lighting by fluorescent lamps lies in the freedom which it can give to architects. This freedom has not yet been fully exploited in this country. Indeed, it seems that some architects are loath to accept the implications of fluorescent lighting. The traditional architectural view of windows as inlets for daylight, and as a means of minimising the use of artificial lighting must give way sooner or later to a more rational view.

Consider modern school buildings. The glass outer walls of new schools are a concession to the prevalent worship of the daylight factor. One should ask—are these enormous windows necessary, or desirable? Is it not sufficient that a window should give to those inside a view of the world outside? Can this not be arranged by a more

modest area of glass? Consider the value of the heat loss through these full-sized windows.

Large windows raise the further problem of what standard of artificial lighting is required in conjunction with them. The argument that money can be saved on artificial lighting is unsound since, however large the windows may be, artificial lighting will be needed on dull days and to even up the illumination at the parts farthest from windows on the many cloudy days. To meet this requirement it has been argued that the higher the daylight factor, the greater is the illumination required to restore the balance. Consider that the eyes of the children farthest from the windows tend to adapt not to their local brightness conditions but to the brightness of the pervading window area. Are we not thus faced with the paradoxical situation that large windows do not render artificial lighting any less necessary but in fact create a need for even higher levels for adequately supplementing the light from them? The serious danger of excessive preoccupation with window size is that it can easily lead to the treatment of artificial lighting as merely a "stand-by" lighting, with a consequent loss of amenity and educational facilities.

Public Lighting

The great improvement in the efficiency of light production by electricity has made its way felt in public lighting as much as in any other sphere. Nevertheless apart from a few prominent examples the general level of public lighting in this country is still very poor.

Considerable progress has been made by our scientists in light production, and our illuminating engineers have produced lanterns and equipment among the best examples known to-day. Is it not this nation's due that we be allowed to undertake this improved lighting on a very much higher percentage of our highway routes than has been allowed in recent years? Such improved lighting can be provided at a cost even less than the "cost" of the accidents themselves.

Table 6

Traffic Accidents

Insurance costs, Gt. Britain ...	£150 million p.a.
Percentage-night accidents ...	30
Estimated cost—night accidents	£45 million p.a.
Present street lighting rating...	£10/£12 ,, p.a.
Estimated cost of additional lighting to give reasonable safety	£3/£5 ,, p.a.
Estimated saving on cost of accidents	£7.5 ,, p.a.

Sports Centres

The recent increase in the use of artificial lighting in sports centres is yet another item to the credit of good and cheap artificial lighting. The pleasure of pursuing one's sport during evenings throughout the year instead of only during daylight is itself a valuable factor.

So far as lighting of football stadiums is concerned, a relatively new venture, the cost of lamps and electricity is a negligible item of the evening expenditure (probably less than .001 per cent. of the evening income) and indeed the rather high cost of the lighting installation can be recovered from the profit gained from only two or three matches.

Conclusion

In conclusion, I would say that the most urgent problem facing the electricity supply industry to-day is the same as that which was so prevalent in the 1890-1900 period, namely the further improvement of load factor. The reason is well known. Expensive plant must be utilised to the full extent; either the peak demand must be limited, or the valleys in the national load curve must be filled in. The first course belongs to the past. The demands for electricity cannot, and should not, be stifled. The second course belongs to the future and in common with any increased use of electricity where greater efficiency in work, in production of output, or in selling is required, must go the question of improved illumination.

Increased lamp, and power station efficiencies have made higher illumination levels economically practicable. Higher illumination leads to extended hours of use. The greatly improved spectral colour of the fluorescent lamp makes it a natural adjunct to daylight and, in some cases, can avoid the costly provision of day-lighting.

Improved lamp efficiencies should not, in general, lead to lower electricity consumption. On the contrary, the gap between the existing and desirable lighting standards is so great that the introduction of greatly improved light sources has opened a tremendous field of development which surely did not exist before. For the same electrical demand as a metal filament lamp installation, the substitution of fluorescent lamps will give more than twice the light output and the additional hours of use will be considerable. This is a benefit that the members of the supply industry must appreciate.

A man is said to be a benefactor to mankind if he can make two blades of grass grow where one grew before. In the production of artificial illumination we have improved well beyond this figure. Electrical engineers can claim some share in this progress; health and comfort and cheerfulness has been brought into the home and hospital, security into the street, efficiency into industry and the office, attractiveness and aid in display into the shop.

What can we do to ensure that these benefits are known to the full by the householder, the ratepayer, the artisan, the shopkeeper and the business man? The supply industry must now play its own special role since the resources for lighting development already exist in the thousands of service centres and by the existing technical sales contacts with its consumers; it can be of the greatest assistance to existing development agencies such as lighting service bureaux, or manufacturers, and to learned societies devoted to improving the science of illumination. This they can do by intelligent liaison and friendly co-operation. The Illuminating Engineering Society brings together all who are interested in lighting from every standpoint. Only by the active support of its members will its great work continue to the benefit of the people.

It is my privilege to address you as a member of the electricity supply industry but I speak as an individual and not as a representative. As an individual may I say how much I look forward to a future made bright, not only by further technical achievements in the production of illumination but to a greater measure of co-operation between all the different agencies concerned, to ensure that the benefits of these achievements are used to the full. This result will not come about without much searching effort. Let everyone of us do some clear thinking on this subject and ask ourselves how we can contribute towards this end.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

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Smith, A. H. ..... 416, Braunstone Lane, LEICESTER.
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Walker, R. ..... c/o Rotary Electrical Co., Ltd., 40, Spring Street, SHEFFIELD, 1.
Willoughby, A. H..... "Braeside," Watford Road, Northwood, MIDDX.

STUDENT MEMBERS:—

Jimpson, B. ..... 11, Mayfair Road, Wythenshawe, MANCHESTER.
LeFevre, D. ..... 11, Stanham Road, Dartford, KENT.

Lighting and Visibility in Mines

By A. ROBERTS, M.Sc., Ph.D., A.M.I.Min.E., A.M.I.M.M., A.M.Inst.C.E. *(Member)*.

Summary

New legislation and new mining methods have resulted in a revival of interest in mine lighting, in which many problems remain unsolved. The mining engineer is required to ensure that the workings under his control are lighted to an extent which provides safe and efficient operating conditions. This paper describes some of the results of an attempt to approach mine lighting from the aspect of visibility underground. The effects of visibility on efficiency and safety are discussed. Typical illumination and luminance levels are described for various underground environments together with some details of the visual tasks which occur in them.

(1) Introduction

The problems associated with lighting in mines have been described by Graham(1), Strachan(2), Wellwood Ferguson(3), and others. Whilst the general features of these problems are therefore well known, their solution is still far from complete. The development of the technique of mine lighting over the past 150 years has been characterised by a spasmodic rate of progress. Recent years have seen a resurgence of interest in the subject, brought about by the twofold impetus of new safety legislation and new mining methods, and under that impetus mine lighting research was revived. The purpose of this paper is to describe some of the work which has been done in a new approach to the subject, made under the influence of this general revival of interest.

(2) Fundamental Considerations

(2.1) The General Background

It must be said at the outset that the attitude of the mining engineer to lighting differs basically from that adopted in most other fields in which illuminating engineering is applied. His attitude is that of a man accustomed to working in the dark. His personal experience and historical background enable him to accept as satisfactory a lighting environment which would not be tolerated elsewhere. The human mind, as well as the eye, is capable of adaptation to darkness. While he will accept unquestioningly that mine lighting should permit work to proceed safely and efficiently, it is not possible to define this in quantitative terms other than the minimum luminance level of 0.01 candle per sq. ft. at the centre of the visual field, which is determined by the necessity to permit foveal vision(4). Lighting provisions over and above this requirement are determined only by the subjective appraisal of what is to be regarded as "sufficient and suitable" general lighting, as is compulsorily installed in certain parts of the mine(5).

(2.2) The Effect of Lighting on Productivity in Mines

The direct effect of lighting on productivity in a coal mine is not easily apparent. In the conventional methods of extraction used in Great Britain the output of mineral depends mainly on the organisation of the working system, which includes such factors as the distribution of manpower, the degree of mechanisation, and the wages structure, together with other factors such as the geological conditions and the methods adopted to control strata movement. The efficiency of working is judged by the cost per ton of mineral extracted, and the achievement of a low cost per ton

The author is Lecturer in Mining at the University of Nottingham. The manuscript of this paper was first received on December 21, 1953, and in final form on July 29, 1954.

requires a high output per manshift. Wage rates are determined by agreement between management and men and are often on a yardage or tonnage basis. Provided the miner has a portable lamp, the agreed task is such that it can be completed within the allotted time during the daily cycle of operations. In these circumstances improvement in the lighting environment by such methods, as, for example, supplementing the portable lamps of the face workers by a mains lighting system, will only add to the cost of production without bringing a higher output per manshift.

It does not follow that because coal face lighting produces no direct effect on productivity on hand loading faces it is not desirable, for there is no doubt that working conditions are improved thereby, and better workmanship is possible.

(2.3) The Effect of Lighting on Safety in Mines

There is also the important effect of lighting on safety. Mining accident statistics are classified and published by the Ministry of Fuel and Power[6]. While it is not possible to deduce any simple relationship between such accidents and the lighting environment, yet there is evidence that in certain types of accident, where visibility is an obviously important factor, the effects of improved lighting are reflected in falling accident trends, whilst in other cases a steadily rising trend exists concurrently with the increasing severity of the visual tasks which is involved in mechanisation of the working system[7].

For example, during the twelve-year period 1941-1952 inclusive the death rate per 100,000 manshifts on underground haulage work decreased from an annual average of 0.11 during 1941-46 to 0.08 during 1947-52. Serious injuries on haulage also decreased from 0.45 to 0.40 per 100,000 manshifts during the same periods. One of the factors which has helped to bring about this result is the wider application within recent years of mains lighting on haulage roads, and its compulsory use at main transport stations since 1947. This is borne out by the figures relating to runaways which resulted in an average of 95 serious accidents per annum during 1941-46 and 61 per annum during 1947-52. On hand haulage, where lighting depends on the portable lamp only, a fall of 30 per cent., between 1941 and 1952, in the number of serious injuries caused by runaways has occurred, attributable to a reduction in the manpower employed on this work, while on mechanical haulage, where manpower has not decreased by any great extent, but where lighting has been improved, serious injuries due to runaways show a decrease of 40 per cent. over the same period.

The link between minor accidents and visibility is shown by the comparative figures for such injuries to surface and underground workers in and about coal mines. The co-ordination of eye and hand, and with body movement generally, very largely determines dexterity and mobility. The need for better visibility underground is evidenced by the fact that, as shown by the figures for 1948, while injuries to hands, arms, legs, and feet comprise some 64.5 per cent of the total minor injuries to surface workers, they comprise the higher proportion of 69 per cent. in underground workers in spite of the greater risk which exists below ground to other parts of the body, particularly to the head and back[8].

There is also a definite relationship between visual performance and accident rates in the various age groups of mineworkers. It is known that, in general, visual performance deteriorates with age, and that this deterioration can be countered by improved lighting[9]. In underground workers, fatalities increase very greatly after the age of 50 years (from 0.86 per 1,000 employees in the age group 41-51 years, to 1.01 in the group 51-61, and 1.22 per 1,000 men of 61 and over), although the majority of these men are not employed on the coal face and therefore the risk attached to their job should decrease, as it does for surface workers of corresponding age at mines, who move on to the less exacting jobs in conditions of better visibility and among

whom the comparable fatality rates fall. (From 0.41 per 1,000 in the group 41-51 to 0.3 per 1,000 in the group 51-61, and 0.38 per 1,000 in the group 61 years and over).

The development of new techniques in the extraction of coal involves an increasing application of machines. Mechanical coalcutters, conveyors, and loaders in British mines totalled 16,300 in 1938, 29,700 in 1947, and 36,900 in 1952. Serious accidents attributed to physical contact with such machines rose from an average of 116 per annum during 1941-46 to 137 per annum during 1947-52. There is thus a trend of increase in accident rate the seriousness of which intensifies as mechanisation increases. It must not be forgotten that many of the personnel involved in such accidents are highly skilled machine operators which the industry cannot afford to lose.

In the application of new techniques to mining it should be possible to break the traditional complacency with which the lighting environment determined by the portable lamp is accepted, for in these techniques productivity depends less upon the man and more upon the machine. The capacity of the machine is greatly affected by the skill with which it is operated. In these circumstances the attainment of good visibility will play an important role.

It is against this background that the work outlined in this paper was begun. It was decided to commence a study of typical tasks as they are performed in the mine, and to attempt to relate these to existing illumination and brightness levels, at the same time making observation with regard to any obvious improvement necessary in the lighting environment. It was felt that the collection and record of such data could be of value in helping mining engineers to plan ahead with intelligence and foresight in order to achieve safe and efficient working conditions in future operations.

(2.4) Basic Lighting Requirements

There are three general classes of locality underground in a coalmine for which the requirements, as far as lighting is concerned, differ considerably one from the other. These are (a) travelling roads, (b) working faces, and (c) haulage stations.

(2.4.1) *Travelling Roads*

The main features of this class of locality are the requirement that men must be able to move at a brisk pace in safety, and the fact that the main body of workmen use the road only for a short period at each end of the shift. Since any one road is used only intermittently for short periods each day, the installation of fixed lighting systems permanently in use along the whole extent of the travelling roads, which usually total several miles in any colliery is not practicable. Even if such lighting were installed, it would still be necessary for each man to carry his own portable lamp to enable him to find his way through the mine in the event of failure of the main electrical supply system, or if the power supply be cut off, as is sometimes necessary.

It would therefore be ideal if the miner's own portable lamp could fully serve to produce adequate visibility on the travelling roads. Before going into this matter, which is concerned with the design of portable lamps, let us consider the essential requirements in other parts of the mine.

(2.4.2) *Working Faces*

The tasks which are performed at the coal face are many and varied but generally speaking the visual task is seldom difficult. The tools used are shovels, hammers, picks, and the like, requiring no great refinement in visual acuity, and where the controls of machinery are to be operated they are seen at close range. The machinery itself, where mobile, generally moves at a slow speed, in which case the time factor is relatively unimportant. Some machines, however, incorporate components moving at high speed, and these ought to be easily visible if men are to work in close proximity to them.

The coal face is a region of great activity, in which a high concentration of machinery and equipment exists. The strata are in a state of constant movement, and,

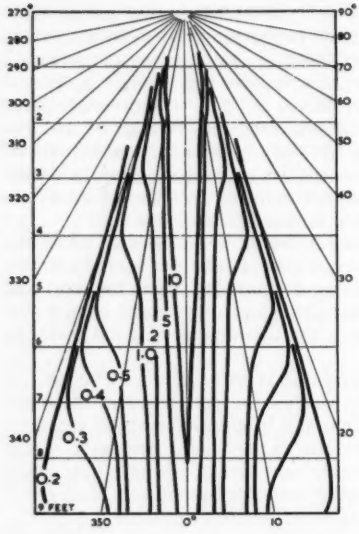

Fig. 1. Iso-foot-candle curves showing light distribution from a cap lamp with polished reflector.

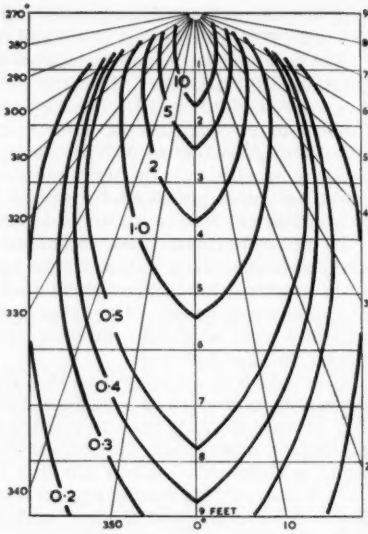

Fig. 2. Iso-foot-candle curves showing light distribution from a cap lamp with matt reflector.

although normally controlled, are liable to fracture and fall on occasion. The coal itself at certain periods, for example after blasting, is unstable. A man at work here is always in hazardous surroundings and he must at all times be on the alert. Even if the requirements of illumination on the immediate task of the miner at the coal face could be met satisfactorily by his portable lamp, yet the supplementing of this by general lighting on the surroundings would still be desirable in order that he may work confidently therein.

(2.4.3) *Haulage Stations*

It is now compulsory (Coal Mines (Lighting) Regulations, 1947. 2.-(I)) to have fixed lighting installed at all haulage stations, engine houses, and similar key positions on the transport system. In these localities many of the difficulties associated with face lighting do not exist. The conditions are more stable, so that the installations can be of a more permanent character and have not to be dismantled and rebuilt day by day. There is more height than is usually available at the face, the surroundings are whitened, and the lighting problems can be compared with similar problems which occur in other fields, such as in vehicular and pedestrian subway and tunnel lighting.

(3) Light Distribution from a Miner's Cap Lamp

Recent years have seen the steady replacement of hand lamps by the cap lamp, which is now generally favoured. The light distribution characteristics of a typical cap lamp of acid battery type, incorporating a 4-volt 0.8-amp. krypton bulb, and fitted alternatively with matt or polished reflector are given in Figs. 1 and 2. Assuming a symmetrical distribution, the iso-foot-candle contours represent the illumination given by the lamp in a direction normal to the axis of projection, that is, if the lamp be imagined to be in use with the beam projected horizontally, it is the illumination which falls on a vertical plane at any distance up to 9 ft. from the headpiece. The

derivation of such diagrams, and their assistance in making possible a true appreciation of the practical value of a certain polar distribution of luminous intensity, is described elsewhere[10].

Whilst it is convenient to discuss the light-shedding properties of a lamp in terms of a working plane normal to the axis of light projection, in fact the working task seldom lies on such a plane. Typical of some of the tasks which might do so on occasion are those of the men concerned in drilling shot-holes, or in blasting, who, for some part of their working time, look directly on to the unbroken coal face which rises as a vertical wall before them. Apart from such tasks, which are in a minority, the worker is concerned with perspectives, sometimes at short range, sometimes at long range, and the visual field alters frequently from short to long range perspective as the man looks up from his immediate task to take in his general surroundings.

(4) Coal Face Lighting

To illustrate what is meant by short and long range perspectives, consider the work of a miner engaged in what is probably the commonest task at the coal face in the majority of mines in Great Britain, hand filling of coal on to a conveyor. Fig. 3 illustrates such a face as it would appear at the beginning of the filling shift. This photograph shows a mains lighting installation, but for the moment let us consider such a face illuminated only by the portable cap lamp which each man wears on his helmet.

The man is required to use pick and shovel to clear away the broken coal blasted from the face, and to throw it on the conveyor belt. He must also set supports to carry the roof which is exposed by the clearing away of the coal. The short range perspective is thus concerned with the use of pick and shovel on the coal, and with holding and hammering supports into position. The long range perspective takes in a view down what is in effect a low tunnel spanned at regular intervals by roof girders or bars which are supported on props running in parallel rows along the length of the face. At one side of this tunnel is the coal face itself, whilst at the other side

Fig. 3. A typical longwall coal face at the start of the filling shift.

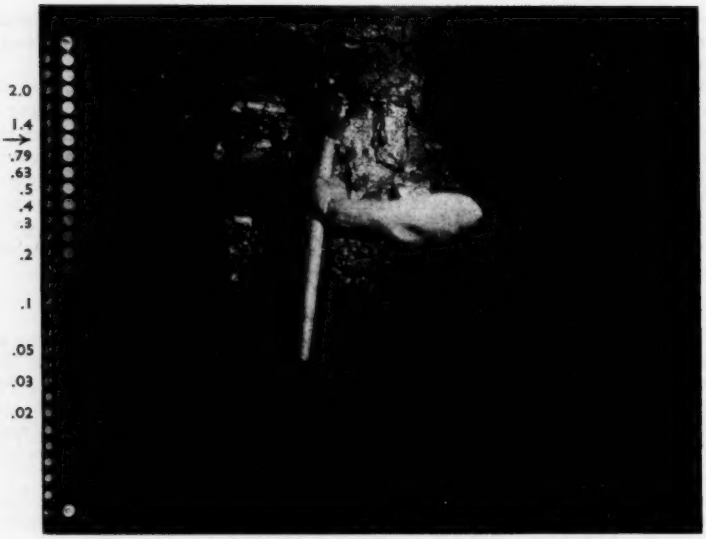

Fig. 4. Miner using pick at coal face. Lighted by cap lamp only.

lies the conveyor, and behind this the "goaf" or waste area from which the coal has previously been extracted.

Fig. 4 shows a miner in the act of breaking coal down with his pick. A luminance scale is included on the photographic negative[11], and this is seen to range from about 0.016 to 2.5 ft.-lamberts. This will be considerably less than the visual range which can only be estimated, since it depends on the eye adaptation level. If it is assumed that, in the absence of glare, eye adaptation is determined by the mean luminance over the visual field, then in the environment shown in Fig. 4 this would be of the order of 0.03 ft.-lamberts and, by applying Hopkinson's curves [12], the visual range, in comfort, can be estimated as extending approximately from 0.001 to 10 ft.-lamberts. On the other hand, if, as has been suggested by Waldram[13], eye adaptation is related to luminance levels within 10 deg. of the object of regard, the visual range will be determined by a much higher adaptation level. Fig. 5 shows a similar task, as represented by the camera placed at the miner's eye position. The central portion of the field of view is well illuminated, there is no difficulty in aiming the pick, and specular reflections from the coal itself give life and sparkle to the illuminated field. Assuming the eye to be adapted to about 0.2 ft.-lamberts the visual range may be estimated as lying approximately from 0.005 to about 40 ft.-lamberts.

Visibility of the coal face tasks is considerably helped by variation in reflection from the several surfaces of coal exposed, and particularly by the contrasts between the specular reflections from the bright parts, usually the cleavage planes of the coal substance, and the duller, more diffuse reflections from the hard bands and from the bedding planes.

Again, when the miner is setting supports, say in the act of hammering up a prop to hold one end of a roof bar, his eyes are fixed on the wooden lid which he must hit squarely with his hammer, to wedge it tightly between bar and prop. The object of vision is only some 2 to 2½ ft. from the lamp and is well lighted in the centre of the beam. The diminution of luminance within the field of view, from the centre towards

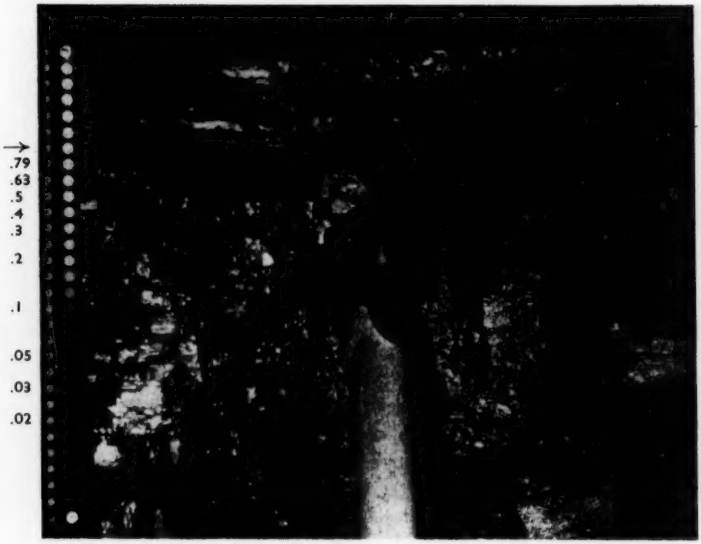

*Fig. 5. Luminance pattern at the centre of the visual field of a miner using his pick at the coal face. (Cap lamp only.)**

the boundary, is well shown by the appearance of the prop in Fig. 6. Also the highlights on the man's arm and hammer, in relation to the prop and the cap lamp, give the general pattern and show the limits of the illuminated field as seen by an observer looking on from one side. The appearance of the task to the man wielding the hammer is quite different however, for he is concerned only with hitting the prop and its lid, and with seeing that they sit securely under the roof bar. These are all easily visible in high contrast, having a luminance of 0.2 to 1.0 ft.-lambert against a background of much lower brightness. Fig. 7.

The ability of the cap lamp to provide for the long range perspective is less evident. Much depends upon the position of the man in relation to the face props. For example, when looking along the length of the face from a position mid-way under a roof bar there are no components in the perspective which break into the central portion of the cap lamp beam. All the objects illuminated, therefore, receive light at very low intensity and are of correspondingly low luminance. Distance to the perspective is given by the small bright patches adjacent to each miner along the face, and by the cap lamps themselves, as their images recede towards the focal point. Contrast between the props and their background is low, and a very great improvement in general visibility could be gained by whitening the supports.

(4.1) Relationship between Illuminated Field and Visual Field at the Coal Face

The importance of perspectives can be studied in relation to the light distribution from the cap lamp and the visual field of the observer. Figs. 8 (a) and (b) are simple

* The density spots on this and accompanying photographic prints represent a portion of the following scale in foot-lamberts :—10, 7.9, 6.3, 5, 4, 3, 2.5, 2.0, 1.6, 1.4, 1.0, 0.79, 0.63, 0.5, 0.4, 0.3, 0.25, 0.2, 0.16, 0.14, 0.10, 0.08, 0.06, 0.05, 0.04, 0.03, 0.025, 0.02, 0.016, 0.014, 0.01.

The actual portion of the scale reproduced varies, being adjusted to correspond with the luminance range of the subject.

It is convenient to regard the luminance level of 1.0 ft.-lambert as a datum; this position is indicated by the arrow.

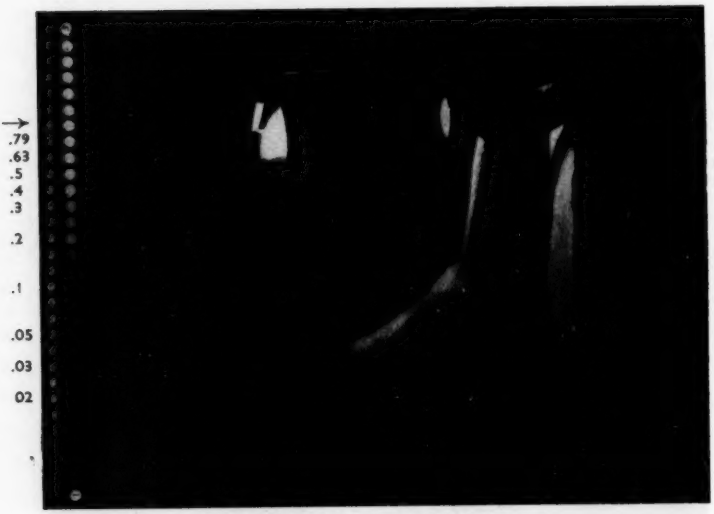

Fig. 6. Miner using hammer to set a prop.

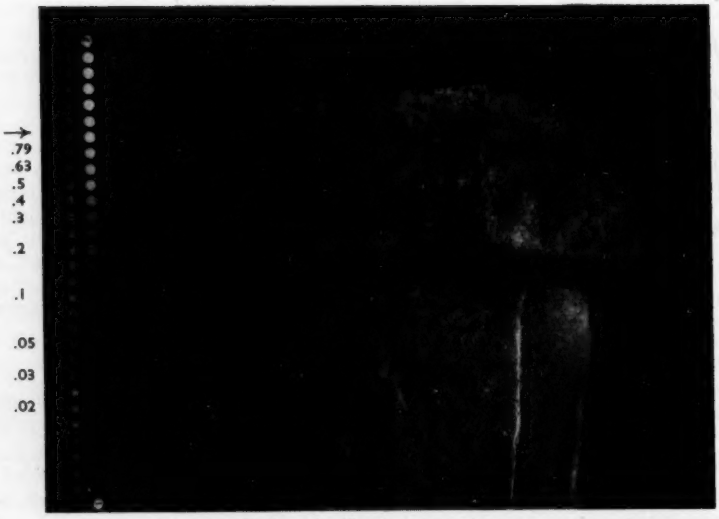

Fig. 7. Visual task of miner setting a prop.

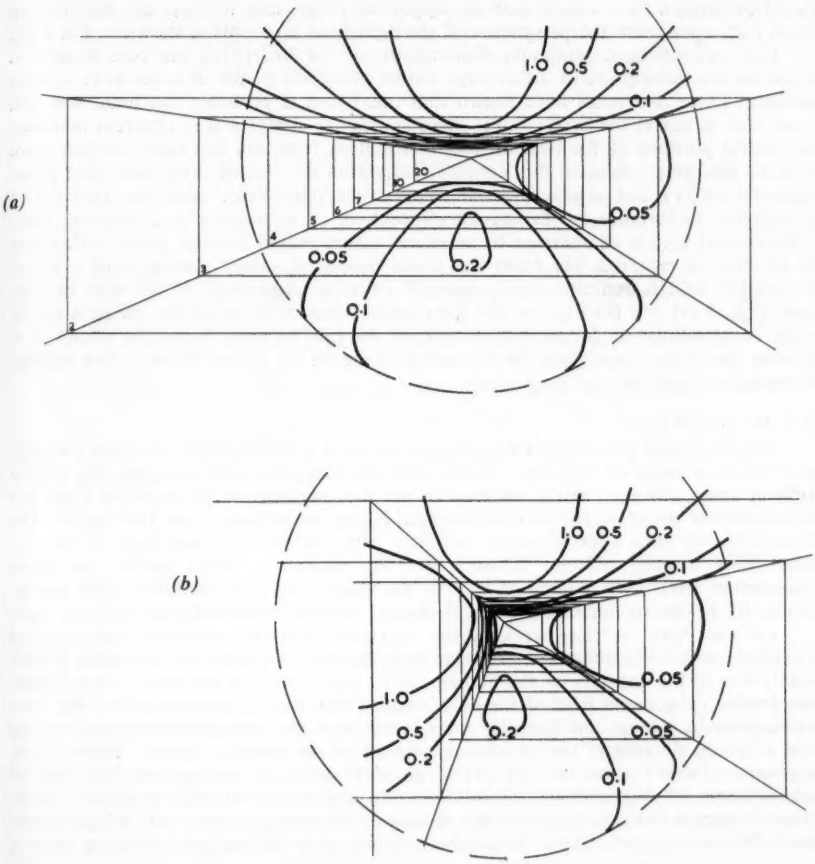

Fig. 8. Scale perspectives looking along a face 4 ft. wide and of effective width 12 ft., divided by a central row of props.:—

(a) iso-foot candle curves showing illumination given by a cap lamp across whole width of face ;

(b) illumination given by a cap lamp on the right hand web of the face and on the central row of props.

scale perspectives looking along a face 4 ft. high, and of effective width 12 ft., consisting of two "webs" each 6 ft. wide. The eye of the observer is assumed to be 3 ft. above floor level and 5 ft. from the coal which runs as a vertical wall on his right. The figures along the bottom left-hand edge of the perspective give the horizontal distance from the observer, in feet. Fig. 8 (a) is the perspective across the whole width of exposed roof, between coal face and goaf. The illumination given by a cap lamp of the type previously described (with matt reflector), and worn by the observer, is plotted on the perspective as iso-foot-candles which represent the illumination falling on a working plane normal to the line of sight. The whole span of width, 12 ft.,

would be divided by a central row of supporting props, and to show the illumination which falls upon them the perspective of the right-hand web only is shown in Fig. 8 (b).

The recommended minimum illumination of 0.4 lm/ft.^{2} at the coal face[14] is based on the assumption of an average diffuse reflection factor of 8 per cent. at that locality. Later researches have shown that this figure is probably too high, and that 5 per cent. is nearer the mark[15]. If these figures are accepted it is apparent that only the central portions of the field of light distribution from the cap lamp contain more than the desirable minimum flux concentration, even on a short range task, and therefore cone vision is not possible over the whole of the visual field. While this may not be of supreme importance, so far as the prevention of nystagmus is concerned, since if the central area is illuminated to an extent which makes fixation possible this may be all that is required, yet from the wider aspect of safety underground a larger illuminated field is desirable and peripheral vision is important. It will also be seen from Figs. 8 (a) and (b) that, on the long range perspective, when the miner is taking in his surroundings, by far the greater part of the field of view, if not the whole of it, receives less illumination than the stipulated minimum for foveal vision, when lighting is dependent upon the cap lamp alone.

(4.2) The Visual Field

The maximum human field of view extends over a lateral angle of about 190 deg. and a vertical angle of 120 deg. In this field the binocular zone occupies the central angle of about 120 deg., and if the eyes do not move relative to the head the right and left monocular zones are reduced and the total lateral field covers about 160 deg.[16]. The binocular zone thus approximately coincides with the distributional field of the cap lamp when a matt reflector is used, but the monocular fields receive no direct illumination from such a lamp at all. In the absence of any additional light source, luminosity in the monocular zones will depend entirely upon reflected indirect light.

The fact that everyday work of the character normally performed underground is possible with little difficulty, so far as completion of the task is concerned, is very largely due to the capacity of the human eye to adapt itself to the surrounding brightness levels. The visual field of the dark adapted eye, that is, for rod vision, has been investigated by Mann and Sharpley who found that the average mean radius of the field of vision differed in the various age groups of the subjects tested. Their results, as given in Table I, show that up to the age of 40 years the average radius of the rod field is about 61 deg. and this diminishes to 40 degrees in the older groups[17]. Wellwood Ferguson has also reported the results of examining some 1,500 miners in the South Wales coalfield, where it has been found that underground workers have a

Table 1

Visual Field of the Dark Adapted Eye
(I. Mann and F. W. Sharpley)

Age group Years	No. of subjects in each group	Mean radius of visual field (rod vision) Degrees	Average for 34 subjects in groups 10 – 30 years Degrees
10 – 20	23	59	61
20 – 30	11	64	
30 – 40	4	61	
40 – 50	3	57	
50 – 60	5	54	
60 – 70	1	40	

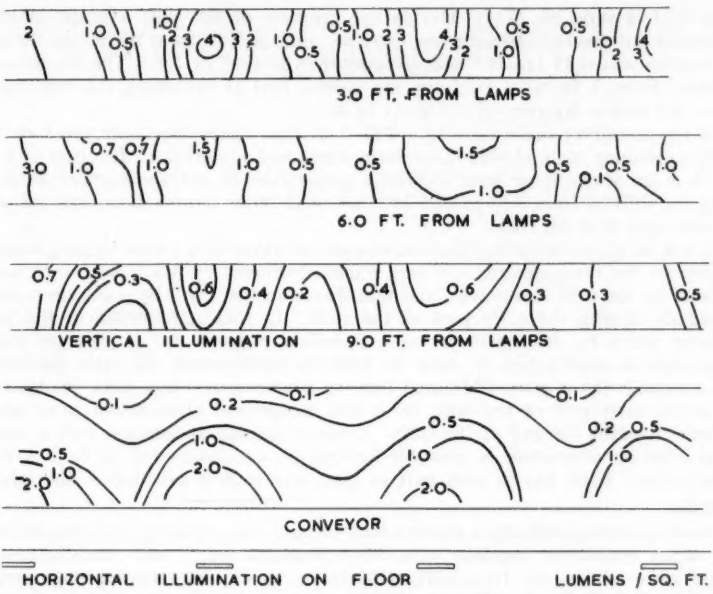

Fig. 9. Illumination given by a mains lighting installation at the coal face.

higher final rod threshold than surface workers, and that this threshold increases with age[18].

These researches apply to conditions of rod vision only, whereas in most underground environments, and certainly on the short range tasks, the eye adaptation level of the miner is such as to permit both rod and cone vision. Further research is needed to give information on the characteristics of the visual field at various adaptation levels over the brightness ranges encountered, but it is apparent that, since the minimum sensitivity of the rods decreases with advancing age, the ability of the miner to make use of peripheral vision at low brightness levels also decreases with age. We ought not, therefore, to rely on eye adaptation ability for peripheral vision in low brightness surroundings.

(4·3) General Lighting at the Coal Face

The failure of the cap lamp to provide adequately for vision on the long range perspective, and the desirability of extending the visible field to include the proper functioning of the peripheral retinal areas, makes it necessary to consider alternative or supplementary lighting arrangements. General lighting systems, if installed at the coal face, can provide an illuminated background outside the effective field of the cap lamp. The character of that background is shown by Fig. 9 which gives the results of an illumination survey on a coal face lighting installation. The seam was 3 ft. 10 in. high and the lamps, which consisted of 40-watt fluorescent tubes in flameproof fittings, were mounted 12 ft. apart immediately behind the conveyor line, and approximately 1 ft. below roof level. During the filling shift the actual working distance of the miner from the line of lamps increased from 3 ft. at the beginning to a little more than 9 ft. by the end of the shift. The illumination on a vertical plane at 3 ft. from the lamps averaged 1.85 lm./ft.^{2}, and the measured diversity ranged from

6.0 to 0.22, a ratio of 27:1. During the progress of the shift average illumination diminished but diversity became less extreme, until at 9 ft. from the lamps the average illumination was 0.33 lm./ft.^{2} and diversity 0.75 to 0.15 or 5:1. The illumination on the floor from 3 ft. to 9 ft. from the lamps, that is excluding the conveyor, was 0.9 lm./ft.^{2} with a diversity of 4.0 to 0.1 or 40:1.

A typical survey made on a face 4 ft. 3 in. high lighted by compressed air turbine lamps, containing twin 15-watt fluorescent tubes and mounted 15 ft. apart at a height of 2 ft. 9 in. above floor level showed a diminution of average vertical illumination during the shift of from 0.54 to 0.20 lm./ft.^{2}, while floor illumination over the working area averaged 0.34 lm./ft.^{2}.

It will be appreciated that the illumination provided by a mains lighting installation of either of the types described is very much obstructed by machinery, roof supports, coal, and by the men themselves, and that therefore there will be many deep shadows, particularly during the early part of the shift. In these circumstances the portable cap lamp worn by each man serves a threefold purpose: (a) it provides him with enough light to enable him to carry on with his work should the main power supply be interrupted; (b) it gives additional light to penetrate the very dark shadows which exist at the early part of the shift; (c) it lifts the general illumination to an adequate task level towards the end of the shift. General lighting at the coal face is thus seen not to offer an alternative to portable lighting by cap lamps but to fulfil a complementary role. Each has its own part to play, and each is essential to the other.

(4.4) Glare

Many practical difficulties are involved in coal face lighting from the mains, and these, when considered together with other problems which such installations bring, notably glare effects, are frequently sufficient to deter many mining engineers from attempting their application. In fact, the great majority have yet to be convinced that anything other than the cap lamp is needed. Obviously, if mains lighting installations are allowed to create glare effects which nullify or substantially reduce the benefits in improved visibility which should result from their application, then there can be no justification for adopting them. If the object of a lighting installation is to improve visibility, then disability glare must be minimised, and it follows that if this is done then discomfort will also be reduced. The glare problem in mines is essentially the same as it is in other fields of lighting. The problem is rendered more acute, no doubt, by the circumstances involved—low mounting height, close proximity to fittings, and so on—but there is no reason to doubt that the same principles which are applied to fittings design and installation in general lighting practice will also serve to reduce glare in mine lighting.

(5) Mine Road Lighting

It is convenient to classify mine roadways as (a) those which are used for travelling to and from the faces and which contain no haulage machinery (pedestrian traffic only); (b) roads containing haulage machinery and used also by pedestrian traffic; and (c) main transport stations.

Outside the immediate vicinity of the shaft bottom visibility depends entirely upon the portable lamp in class (a) roads. Class (b) roads often do not contain general lighting outside the transport stations, but there is much to be said for lighting them permanently throughout, as although the general body of workmen are prohibited from using the road while the haulage system is in motion, there will always be a steady, though sparse, pedestrian traffic by other "authorised" persons. In class (c) localities general lighting is compulsory.

(5.1) Relationship Between Illuminated Field and Visual Field in Mine Roadways. (Cap Lamp Only)

The earlier remarks relative to the limits of the visual field and the importance of peripheral vision apply equally on the travelling roads as on the faces. On these

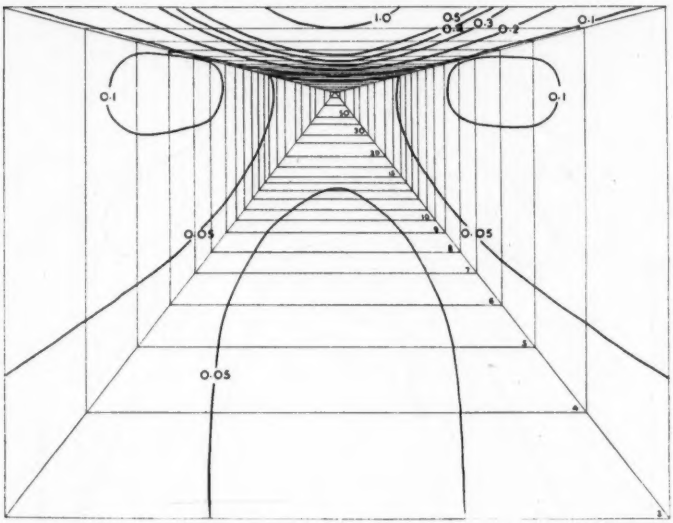

Fig. 10. Scale perspective of a road 8 ft. wide by 6 ft. high showing illumination (lm/ft²) given by cap lamp on the helmet.

roads a man is concerned with (a) establishing a direction of orientation; (b) moving in that direction clear of obstacles; (c) placing his feet securely to obtain balanced movement and thus to avoid tottering and stumbling. The road is seldom unobstructed and the extent to which the cap lamp can meet its requirements depends very largely upon the position in which it is carried and the dimensions of the road.

Figs. 10 and 11 illustrate the conditions which exist in a road measuring 8 ft. wide by 6 ft. high, with two alternative lamp positions. In Fig. 10 the lamp is assumed to be worn on the helmet in the normal way, at a height of 5 ft. from the floor. In Fig. 11 the headpiece is detached from the helmet and carried in the hand at a height of 2 ft. 6 in. above floor level. In practice, vision of obstacles on roof and floor is necessary. When walking along a mine roadway—and this is customarily done at a brisk rate—the eyes are directed rapidly upwards to take in the roof and general perspective, then downwards to observe the floor and pick out the path. It will be apparent from Fig. 10 that as the cap lamp is normally worn it cannot provide for visibility on the floor adjacent to the wearer, and that falls and stumbling are likely to result. In fact, it is only by removing the headpiece from the helmet and by using it as a hand torch that the light beam can be directed to permit fixation on roof and floor as the need arises.

(5.2) Haulage Roads Used Also as Travelling Roads

It is common practice in this class of roadway to have mains lamps in fittings spaced at intervals along the road centre or sometimes at the road sides. The purpose of such an installation is to give warning by vision of an approaching set of trucks, so that an individual can either take refuge in the nearest manhole or, in a slow speed haulage system, see that there is ample room for the trucks to approach and pass him in safety.

Distant vision of approaching trucks depends very largely upon recognition of a silhouette against the lighted areas of the road, the bright patches of which appear

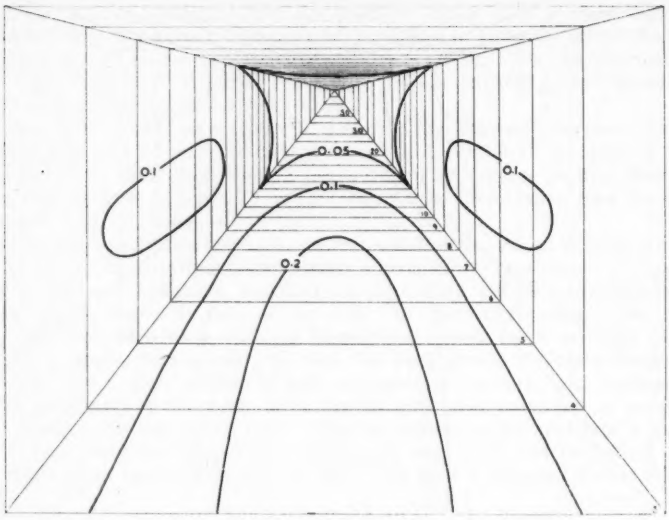

Fig. 11. Scale perspective as for Fig. 10, showing illumination given by a cap lamp when the headpiece is carried in the hand.

to coalesce towards the far perspective. When the lamps are positioned centrally along the road this silhouette is less easily seen than it is when the lamps are at the road sides, for in the former case the sides have practically the brightness of the approaching trucks whose outline is consequently defined only towards the road centre, whereas in the latter case the road sides form a brighter background against which the complete outline of the trucks can be seen. As the trucks come to closer range they pass alternately through the bright patches near each lamp, then into the intervening shadows. It is important that recognition of them should be possible continuously so that an effective judgment of speed and distance can be made. If the lamps are too widely spaced, constant and clear definition is not easy because the trucks tend to disappear into the intervening shadows between the lamp positions. This condition is aggravated by glare from the nearest lamps, particularly when they are of the transparent well-glass type, in which case much of the general field of brightness between adjacent lamps may lie below the threshold. Better visibility is promoted by raising the luminance of the truck ends by white paint, and by controlling the light distribution from the fittings to minimise glare.

(5·3) Lighting Main Transport Stations

The compulsory requirements at transport stations underground refer to "sufficient and suitable" general lighting. This is defined by stating that the illumination over the whole area shall enable men to work or pass safely and efficiently without the aid of a portable lamp[19]. It is pertinent to point out that the same Regulations also enforce a requirement that all persons employed in haulage operations shall wear and use an electric cap lamp. It is manifestly illogical to insist on the wearing of a cap lamp and then to judge the adequacy of the lighting environment by the conditions which exist when that lamp is not in use. Since it is necessary to provide every miner with a portable lamp capable of giving him light over the whole underground work shift, common-sense economics demands that it should be regarded as an integral part

Table 2

Floor Illumination on Mine Haulage Roads

Installation	Locality	Type	Character of Surroundings	Road Width ft.	Lamp Height ft.	Lamp Spacing ft.	Illumination on Floor (lm/ft²) Max.	Min.	Av.	Diversity Ratio
(a)	Pit Bottom	Fluorescent. Twin 80-watt lamps. Open type reflectors	Rectangular. Walls bricked, lagged, newly whitewashed	16	9	16	10	1.0	5.3	10 : 1
(b)	Pit Bottom	Fluorescent. 80-watt lamps in transparent enclosures. Not inset in roof	Rectangular. Walls bricked. Roof lagged. Whitewashed	12	7	15	10	1.0	3.9	10 : 1
(c)	Main level Approach to Pit Bottom	Fluorescent. 80-watt lamps in industrial dust-tight enclosures. Inset into roof	As for (b)	18	8	30	5	0.2	1.6	25 : 1
(d)	Haulage Road	Filament. 60-watt lamps in transparent well glass	Rectangular. Walls bricked. Roof part lagged. Whitewashed	10	7	30	3	0.1	0.9	30 : 1
(e)	Haulage Road	Filament. 100-watt lamps behind opal panels inset into sides	Arch. Smooth concrete. Whitewashed	12	7.5	7.5*	0.4	0.1	0.3	4 : 1
(f)	Haulage Road	Filament. 60-watt lamps in prismatic bulkhead fittings	Arched. Lagged and whitewashed only to height of 4 ft.	12	7	7.5*	0.12	0.04	0.11	3 : 1

*15 ft. apart staggered on alternate sides.

of the lighting system, and that if it can make an effective contribution in determining the visual environment of the worker, that contribution should be taken into account. The proper function of the cap lamp then becomes to spot-light a task which is performed in surroundings illuminated by the general lighting system as background lighting. The present legal requirement, where general lighting is compulsory, lays down that this background lighting must also provide efficient task lighting.

A useful approach to this problem is to regard the primary function of the general lighting as being to combine with the effect of whitened surroundings in determining the eye adaptation level. If the installation is carefully designed to avoid glare the effect of this will be to extend the visible brightness range and it may well be that, in some cases, adequate task visibility will result. In any event, in such an environment the particular tasks can be studied and suitable measures devised if required, for the achievement of adequate task visibility, This will often demand the application of additional local lighting, as is customary in factory and workshop practice above ground, but it will also be found that the portable cap lamp itself is not infrequently the most practicable method of providing that local lighting in the particularly difficult circumstances which often exist underground[20].

(5·4) Illumination Levels Achieved by Typical Mine Roadway Lighting Installations

Table 2 gives details of six haulage road lighting installations, representative of some of the various systems in general use, with the results achieved, in terms of average lumens per sq. ft. and diversity on the floor. It will be seen that, as exemplified by installations (a) and (b), high level illumination with moderate diversity is possible when fluorescent lamps are used. A characteristic here is that the visible tubes give noticeable glare, but if the walls and roof are whitened the effects are not excessive. In installation (c) the tubes were hidden. This eliminated glare but the distributional efficiency was also reduced. Diversity here was high due to the too wide spacing of

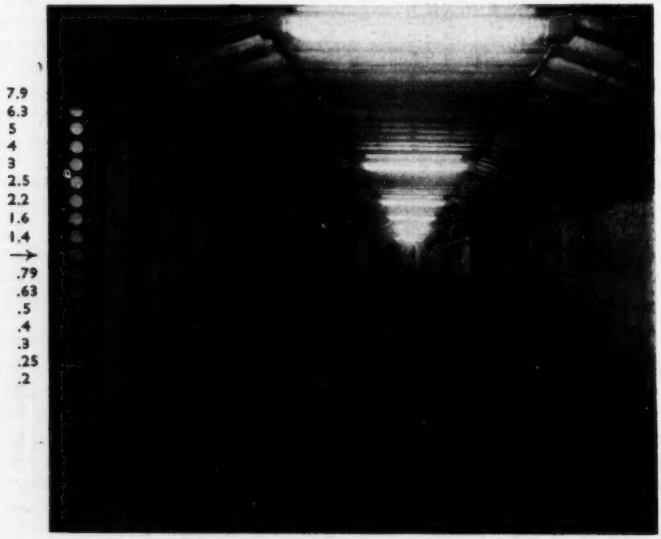

Fig. 12. General view along mine haulage road lighted by fluorescent lamps in transparent enclosures.

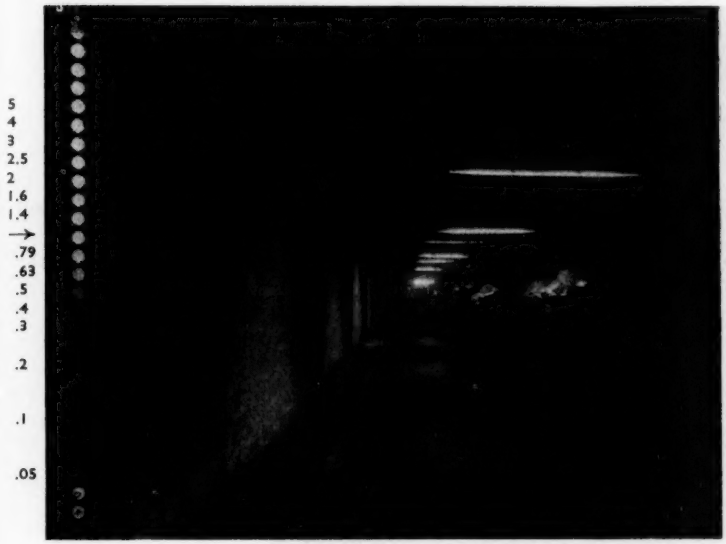

Fig. 13. Mine roadway lighted by fluorescent lamps in industrial type dustproof fittings inset into roof.

the lamps. Installation (d) gave considerable glare and a high diversity with low average illumination, while in (e) and (f) there was no glare and distribution was uniform but at low level.

(5.5) Luminance Range of Surroundings in Typical Mine Roadway Lighting Installations

Fig. 12 is a photograph of an installation of type (b) while a type (c) installation is shown in Fig. 13. It must be made clear that the primary purpose of the photographic illustrations to this section is to record the luminance range, within the limitations of the method, on each of the subjects depicted. It is only when the tone range and density level of the luminance scale happens to be the same on two subjects that qualitative comparisons may be made. Details of the scale are given in the appendix at the end of the paper.

It will be seen that the installation shown in Fig. 12 achieves a comparatively high and uniform luminance level. If the average luminance may be taken as indicative of eye adaptation, in such an environment this would be about 1 ft.-lambert so that the visual range in comfort is of the order of 0.05 to 100 ft.-lamberts. In the particular field illustrated there is no important detail below the brightness threshold and the lamp tubes themselves have a brightness which does not exceed the comfort limit by any great extent. In Fig. 13, on the other hand, there is a pronounced tunnel effect. More use could be made of the potential reflectivity of roof and sides by directing the light on to them and not on the floor. In this example the average luminance of the subject is of the order of 0.15 ft.-lambert and the visual range is correspondingly affected.

One of the difficulties inherent in mine roadway lighting is that, whilst it may be relatively easy to light an empty roadway adequately, it is quite another matter to cater for all requirements in that road under working conditions. Figs. 14 and 15 illustrate a typical example of a pit bottom where the total available height is reduced

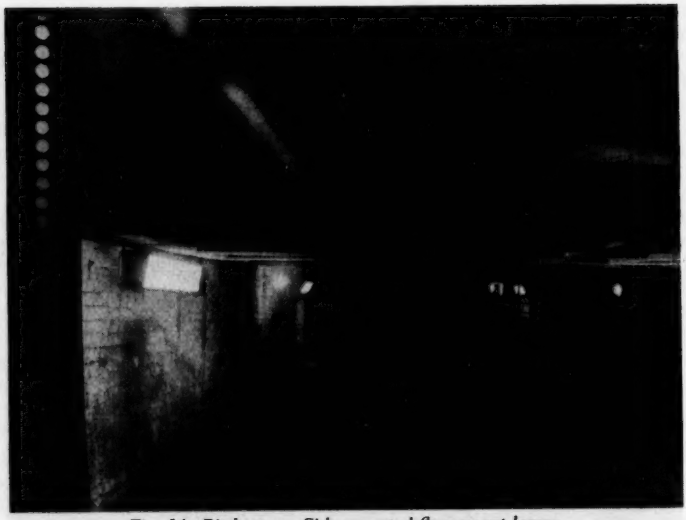

Fig. 14. Pit bottom. Side mounted fluorescent lamps.

Fig. 15. Appearance of same pit bottom as in Fig. 14 when coal is being hoisted.

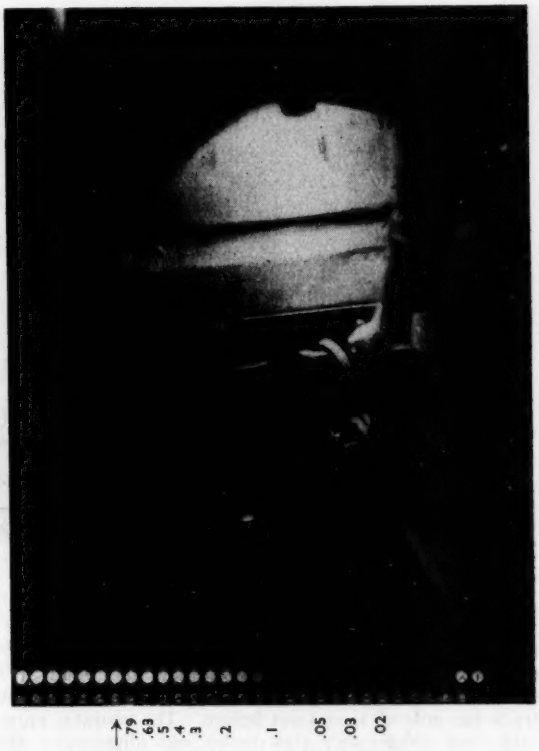

Fig. 16. Task position when clipping trucks on to haulage ropes.

by the necessity to erect an intermediate loading platform between roof and floor, so that trucks can be loaded simultaneously on to the shaft cage at two levels. Fig. 14 shows the lower level in which the available height over a span of 18 ft. is little more than 5 ft. The general appearance of the shaft bottom under working conditions, when both levels are full of trucks, is seen in Fig. 15.

(5.6) Task Visibility in Mine Roadways where General Lighting is Installed

The characteristics of the visual tasks underground are varied and it is necessary to observe typical examples, as they are being performed, in order to appreciate the circumstances involved. The difficulty of ensuring adequate task visibility by a general lighting system on a haulage road has already been mentioned. One of the most common tasks in such situations consists of coupling and uncoupling trucks and of attaching and detaching them from a moving haulage rope. These are tasks which must necessarily be performed not only in the shadows between the trucks but also in such a position that direct light from the roadway is obscured by the worker's body. The detailed examination of such a task is described elsewhere[21], but the illustration (Fig. 16) will serve to show the value of the cap lamp as a method of providing supplementary local lighting. One can imagine many other fields of activity outside mines where such a lamp could find a useful place.

Whilst the value of applying whitewash and cement to the roof and sides is generally appreciated, where mains lighting is employed underground, very little

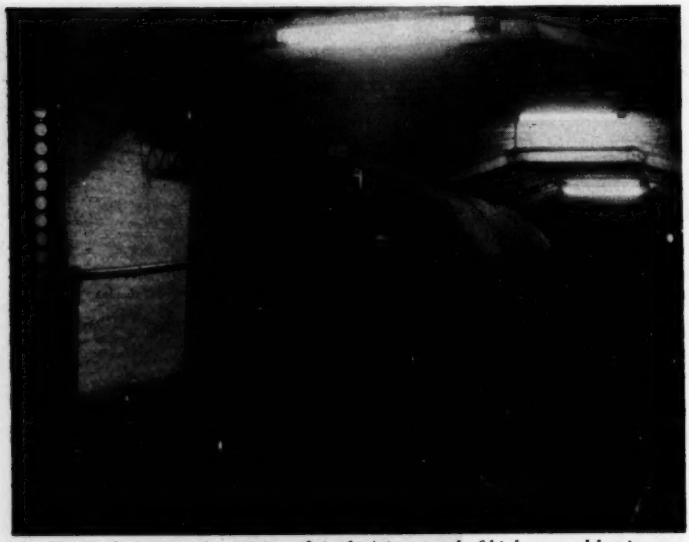

Fig. 17. Task position (operation of tippler) in a road of high general luminance.

use is made of the selective application of white paint to portions of the visual field in order to improve visibility by accentuating contrasts. The possibilities of improvement in this direction are very great, and apply to a wide variety of conditions. For example, Fig. 17 shows a task position in a road of high general luminance. The controls of the tippler must be operated so that it begins to turn as soon as the truck has entered it and not before. The operator must see the truck end and tippler arch, and judge when they come into alignment. Obviously, no matter what the illumination level, if both truck and tippler have the same reflection factor they will also have the same luminance and contrast between them will be low. Either the truck end or the tippler arch could be painted white to intensify the contrast between them.

(6) Conclusion

The work which has so far been done represents no more than a preliminary exploration of the subject of visibility in mines. The interpretation of the observed data requires sound judgment and demands a combination of experience of the environments concerned and understanding of the complicated and intangible process of vision and all that goes to make up visibility. Photographic methods are useful in that they make possible the presentation of some aspects of the problem to those who are experienced in the wider field of illuminating engineering but who have not the opportunity of personal experience of the underground environment. The mining engineer and the lighting engineer are enabled to discuss the problem together and to interpret the data thus presented. This can only result in the furtherance of progress in mine lighting for the mining man, fortified by the specialised advice of the lighting expert now available to him, can return to the task of obtaining additional, more detailed, and more precise data appertaining to the underground scene without dissipation of time and energy on unfruitful lines of investigation.

Whilst it is unwise at the present time to draw specific conclusions, yet it is possible to observe the results of the present illumination and luminance studies in

relation to the published work of those lighting engineers who are active in the field of luminance—luminosity correlation. In this way we may assess the eye adaptation of a miner engaged on a coal-face task in the absence of mains lighting to range from the order of 0.03 ft.-lambert to about 0.2 ft.-lambert, being higher on the short-range tasks than on the long-range perspectives. By applying Hopkinson's curves the instantaneous visual range without glare at these adaptation levels can be estimated as extending from thresholds of the order of 0.001 to 0.005 ft.-lambert, to glare at 10 to 40 ft.-lamberts.

If glare sources are visible then adaptation will be a more involved process. Where mains lighting is installed on a hand-loaded face the miner generally works on the short-range tasks with his head averted from the incident light, i.e., with his side or back to the line of lamps. It is only when he turns to cast his spade full of coal on to the conveyor that he experiences glare effects. Since this periodical and momentary exposure to the light sources gives a series of glare shocks to the visual process, and also since there is no need to discriminate detail when casting from a shovel, it is possible that discomfort is more evident and more important than disability in such circumstances.

In a laboratory investigation of discomfort glare at the surround brightness levels encountered in mines, J. R. Wakefield has employed Hopkinson's multiple criterion method of subjective appraisal. The published results of his preliminary study showed that, assuming adaptation to be at a surround brightness of 0.03 ft.-lambert, source brightnesses of from 65-100 ft.-lamberts were judged to be acceptable, 100-300 ft.-lamberts uncomfortable, and higher brightnesses intolerable. At the surround brightness of 1 ft.-lambert source brightnesses below 100 ft.-lamberts gave imperceptible discomfort, 100-350 ft.-lamberts were acceptable, 800-2,500 ft.-lamberts uncomfortable, and higher brightnesses intolerable. These figures were obtained with a source size of 0.0011 steradians[22]. The surround brightness of 1 ft.-lambert corresponds to the adaptation level in a well-lighted mine roadway, and the instantaneous visual range without glare in such an environment is estimated from Hopkinson's curves to be from about 0.01-100 ft.-lamberts.

The intermittent glare effects which are characteristic of coal-face lighting installations are generally absent from visual tasks in mine roadways, where continuous exposure to the lamps is more common. Disability assumes more importance than discomfort here. It is hoped to be able to follow the laboratory study of discomfort glare by a similar study of disability glare in mine lighting. This should furnish valuable data on the subject, but in the meantime much can be done to improve visibility on mine roadways by applying existing knowledge of the fundamentals of glare and visibility as described in the papers of Holladay, Stiles, and others.

Observation of the underground scene makes some generalised conclusions possible. For example, it is apparent that the cap lamp, as at present designed, leaves much to be desired. Future developments could usefully be directed towards the attainment of a wider effective angle of light distribution, in cases where the portable lamp must provide the sole means of lighting, at the expense of maximum beam intensities which are a source of glare to others. Specular type reflectors, producing a concentrated beam, are being increasingly applied, mainly on account of the changes in the character of the task in mechanised operations where the atmosphere is more dusty than is the case in non-mechanised mining, and where the visual task often contains the necessity to observe detail at greater distances from the eye than is characteristic of hand loading. This can only result in the virtual restriction of the effective visual field to the central retinal areas. It is therefore essential to supplement such cap lamps by some other means of lighting on the surroundings, if adequate visibility is to be ensured. On the other hand, in circumstances where general lighting is used,

as on haulage work, the portable lamp can serve a very useful purpose as a supplementary spotlight.

The problem of mine lighting can only be satisfactorily approached from the aspect of visibility at the precise localities concerned. All the factors affecting visibility, and their interdependence, must be taken into account. In particular, it should be realised that to plan in terms of illumination alone, under the circumstances which exist underground, will often result in the creation of unsatisfactory conditions, principally on account of glare effects and the limitations imposed by available space on the relative positions of fixed lamps and working task. The determination of " sufficient and suitable " general lighting requires a study of the tasks performed in the mine in relation to the planned provision of light. The purpose of this paper has been to describe some of the results of an attempt to bring such an approach to the subject.

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Home Lighting

By ARTHUR H. YOUNG, A.M.I.E.E. *(Member)* and C. J. MISSELBROOK, B.Sc.(Eng.), *(Fellow)*.

Summary

This paper reviews developments in domestic lighting from 1928 to the present and endeavours to show some possible lines of future progress. The large range of materials used in the manufacture of lighting fittings designed for the domestic market is discussed.

The problems of lighting various rooms in the home are considered and the possible reasons for the lack of interest in fluorescent lighting are analysed. Suggestions for the developments necessary before fluorescent lighting can be introduced successfully into the domestic lighting field are made. A plea is made for an approvals system to be applied to lighting fittings designed and sold for domestic use to ensure adequate safety.

British, Continental and American practice is compared and the need for better collaboration between lighting engineers and architects is stressed.

(1) Introduction

Nearly one thousand new homes are being completed every day in this country and it is appropriate that some indication of present-day methods of lighting them should be given before this Society. Little has been published by the Society on this aspect of lighting, possibly owing to the large part which personal preference plays in the selection of lighting for the home. Accordingly, this subject does not lend itself to the same detailed objective analysis as some others, but the changes which have taken place over recent years are full of interest and the present building programme presents a challenge to the lighting industry.

(2) Domestic Lighting 1928-1954

(2.1) 1928-1930

In reviewing lighting in the home the year 1928 has been taken as the starting point, as it was in this year that an important change in the pattern of lighting and lighting fittings began to take shape. Before that date the houses of this country were lit either by imitation gas and candle fittings in metal and wood with parchment or silk shades, or by alabaster bowls on chains. The amount of light in any room was negligible.

About that time, however, the architects of the so-called "modern school" were beginning to build modern buildings and homes in which these types of fittings were incongruous. This fact, coupled with the cheapening of electricity supply tariffs, led to the demand for more light and better designed fittings.

In an attempt to stimulate the interest of architects, designers and the public in the use of fittings in keeping with modern interiors, a specially designed lighting showroom was opened in London and a range of modern fittings was brought over from Paris. The interest in this experiment was so great that the company concerned engaged its own designer and started to make fittings to his designs.

(2.2) 1930-1939

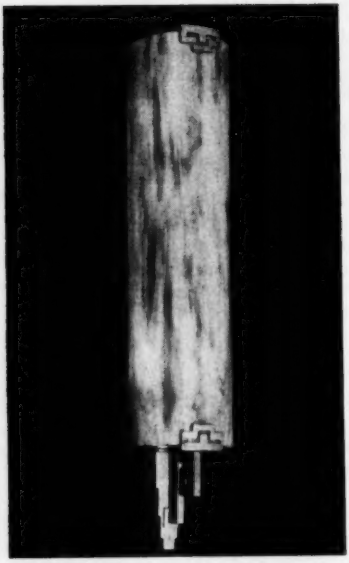
Between 1930 and 1939 a large number of public buildings, houses and flats were built in this modern idiom and the interiors were soon being illustrated in the technical journals and magazines, so that the influence of modern design began to spread. The furniture, furnishing fabrics and wallpaper industries were gradually moving towards similar simple functional designs, avoiding the over-decoration of previous years.

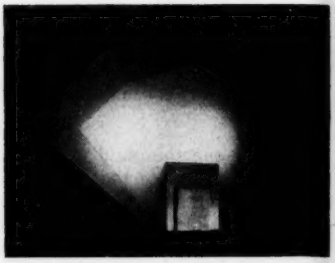
An attempt was made to bring some form of standardisation into the field of

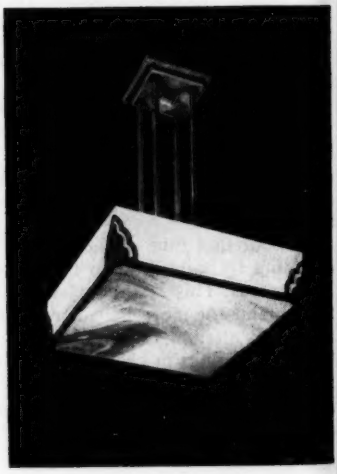
The authors are with Troughton and Young, Ltd. The manuscript of this paper was first received on March 3, 1954, and in revised form on April 13, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 21, 1954.

decorative lighting by the introduction in 1936 of B.S.S. 710(1), " An Electric Study and Reading Table Lamp." This was revised and re-issued in 1948 under the title " Electric Reading Lamps." Little enthusiasm was shown, however, by manufacturers and no table or floor standards are being made to-day which comply with the specification.

At the beginning of this period the metalwork of most fittings was made from brass and chromium or bronze plated; the thick opalescent glass shades had very low transmission. Later, however, three-ply flashed opal glass with high transmission came into general use and the advantages of aluminium began to be apparent. Typical fittings of the period are shown in Figs. 1-5.







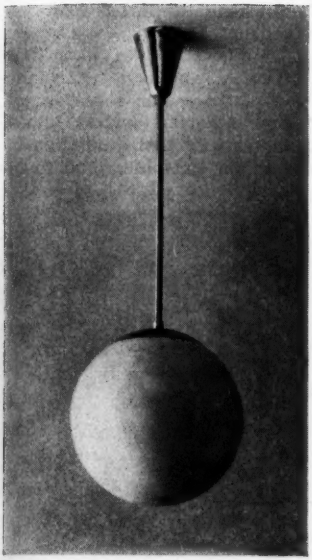
Figs. 1, 2 and 3. Two wall brackets and a pendant showing early types of modern fittings.

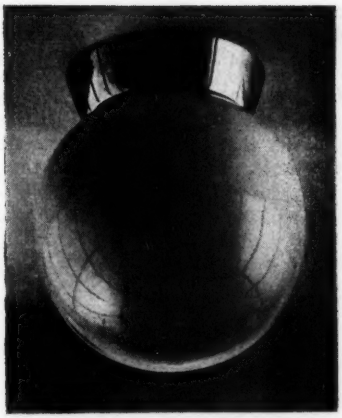
(2.3) 1939-1945

During these years no fittings were designed or manufactured specifically for the home.

(2.4) 1945-1947

The manufacture of domestic fittings to pre-war designs started again under very difficult circumstances. Materials were in short supply and trained designers were not available. Manufacturers had also to contend with the heavy burden of purchase tax on all domestic lighting fittings and it was unfortunate that some encouragement was





Figs. 4 and 5. A pendant and ceiling fitting designed in the early 1930s.

not given to manufacturers by means similar to the admirable scheme for Utility furniture, which did so much to re-start that industry. However, in spite of these adverse factors a start was made on the gigantic task of satisfying the demand for re-lighting peace-time homes.

(2.5) 1947-1951

In an endeavour to stimulate our export trade, the Government sponsored the "Britain Can Make It" Exhibition. Many new ideas in the design of rooms, furniture and furnishings were to be seen, but the large majority of the lighting fittings were of pre-war design.

This state of affairs led the same company, which in 1928 produced the modern fitting, to cause a stir in the industry by introducing lighting fittings of entirely new conception. These incorporated a simple but attractive spun metal reflector housing the lamp and fitted to the lampholder in such a way that it could be turned through 360 deg. without moving any other parts of the fitting or disturbing the wiring (Fig. 6).

Another attractive feature was a series of pierced holes in the reflector which lightened the possible dull effect of a comparatively large area of undecorated metal. This reflector was the basis of a range of fittings including a pendant, three wall brackets and a table and floor standard. The brackets, table and floor standards were made more versatile by means of a universal joint which enabled them to be adjusted in the vertical and horizontal planes. All this was done in an attempt to meet the requirements of the times when many people were living under conditions in which one room had to be used for more than one purpose, such as a dining- and living-room or a living-room and office. One fitting had to be used to suit more than one purpose. Flexibility and ease of adjustment were necessary.

Owing to its success, this particular range of fittings was extended by the addition of other pendants and brackets with different finishes for the reflectors and various materials for the shades. This reflector with its smooth lines, suggesting traces of

Scandinavian influence, began to be seen everywhere and eventually started a number of manufacturers designing on similar lines.

A table lamp of this period is shown in Fig. 7.

(2.6) 1951-1954

It was the Festival of Britain, however, which convinced the lighting fittings industry that their designs were not suitable for the architecture and decoration of the times. It will be recalled that all equipment used in the exhibition had to be accepted by a Design Panel of the Council of Industrial Design. When it was discovered by some manufacturers that their fittings were not acceptable to the panel and when they saw the extensive use of contemporary lighting fittings throughout the South Bank Exhibition, the need for action was apparent. In only three years since then the number of manufacturers with ranges of contemporary fittings has jumped from two to three to more than a dozen. All the main manufacturers of domestic lighting fittings now include such fittings in their ranges; two typical fittings are shown in Figs. 8 and 9. To-day the architect, interior designer and user have a wider range of well-designed domestic fittings from which to choose than ever before. Earlier this year, before this Society, one of the leading industrial designers actually pleaded for a halt in the design of new lighting fittings as he considered there were already too many of a reasonable standard of design from which to choose.

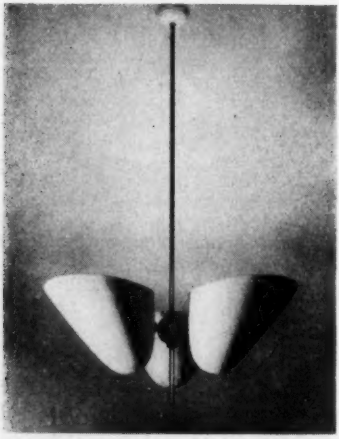


Fig. 6. Pendant showing pierced metal reflectors which can be rotated.

Fig. 7. Table lamp open at the top for upward light.

It has always been difficult for the general public to see and buy well-designed and well-made lighting fittings. Their local electrical contractor perhaps had one or two pendants hanging up which had been in his premises for years. The local electricity supply authority probably had more modern and spacious premises and were more alive to the retail trade. They had a few more fittings of a more up-to-date nature. A very few of the larger department stores had some reproduction metal chandeliers and brackets. To-day the story is very different, due again to the realisation that decoration, furniture, furnishings and lighting fittings should be considered together. The people who are alive to this are the progressive stores throughout the country who are finding that by displaying lighting fittings with their furniture their sales of these have increased beyond recognition. To-day in practically every town

throughout the country there is at least one store or furniture shop where contemporary lighting fittings can be purchased. This is a sad reflection on the electrical contractor and retailer—the traditional outlet for the lighting fittings trade. More often than not his premises are not in a reasonably accessible part of the town, and even if they are, he has not gone to the trouble or the expense of providing surroundings to show off the modern fittings to advantage. The success of those few contractors who have developed modern showrooms should be an example to the others.

The user is much better looked after by the many magazines, from the cheaper weekly to the glossy monthly. Here they are not only shown various types of fittings suitable for their home, but sometimes are even told how to make them! They are also shown complete designs for rooms and told where to buy the equipment. The building of houses with their decorations, furniture and lighting have also been shown

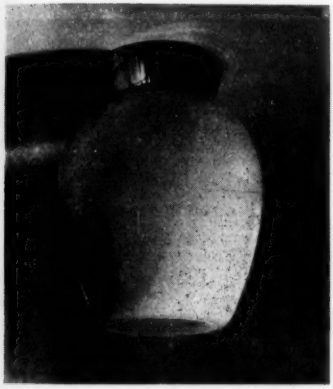


Fig. 8. A ceiling fitting with open base glass; a development from the earlier sphere.

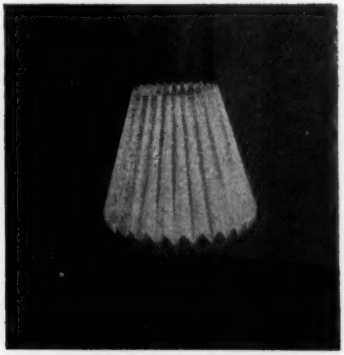


Fig. 9. A simple table lamp.

on television. All this indicates the greater interest and appreciation of a wider range of people for better-looking furniture, furnishings and lighting fittings for their homes.

(3) Materials

The materials used for fittings to-day are very much more interesting and varied than 15 years ago. This has been influenced by the shortage of metals since 1945 and by developments in synthetic plastics.

Aluminium is being used extensively for the many reflector shapes now popular. Apart from its ease in spinning, high quality finishes which are both beautiful and durable may be obtained by the anodising process.

Glass has been the traditional diffusing material since the electric lighting fitting was first made. Great improvements have been made in manufacturing techniques over the years, and to-day glasswear in the high quality three-ply white flashed-opal glass has a light output ratio around 94 per cent. This type of glass in blown shapes is used extensively to-day on the commercial type of fitting used domestically in bathrooms, kitchens, etc. For the more decorative fitting, glass is not now used so extensively in this country. Some of the reasons for this are possibly: (i) High overall cost, due to expensive tooling, wastage in manufacture and breakages in handling

and transport; (ii) Lack of new developments from glass manufacturers; (iii) Development of plastic materials.

Acrylic plastic has been used in large quantities since 1945, and some quite hideous shapes have been evolved—partially because of the ease of manipulation of the material under heat, and the comparatively low cost of tooling. However, where designers have been consulted it has been used successfully for diffusing bowls for tungsten fittings and as enclosures for the fluorescent lamp. This material is, however, still too costly to be used for the more inexpensive fitting.

There is also another material, marketed as "Chrysalline," which is sprayed on

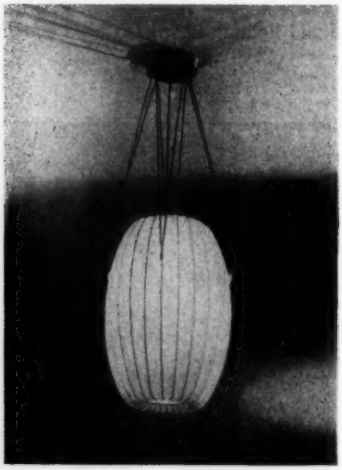


Fig. 10. One of the latest designs of fitting using Chrysalline.

to a wire frame to form an enclosure, and was first used to any extent for lighting at the Battersea Pleasure Gardens in 1951. It was used again for outdoor illuminations during the Coronation and is now being used on a small scale for domestic lighting fittings (Fig. 10).

Thermosetting plastics have not been used to any great extent in domestic lighting fittings except for the well-known "Coolicon" shade and the galleries for all insulated fittings. The necessity for expensive tooling means that large runs of fittings have to be laid down, which is not usually an economical proposition for the more decorative type of domestic lighting fitting.

A large variety of materials is used to make shades. These range from silk, through furnishing fabrics to parchment, and from cellulose acetate to printed cardboard. As the majority of these shades are for use with tungsten lamps the problem of dissipation of heat must always be studied. In addition, a factor which is not always considered is the cleaning of these shades. A very important advantage of the plastic materials is that they can be either washed in warm water or, at least, cleaned with a damp cloth.

(4) Lighting Planning

For a number of years successive investigations by numerous authorities have gradually led to a better understanding of the methods of applying artificial lighting and the numerous factors which have to be considered have been well set out by Ackerley(2) and others. The I.E.S. Code gives the recommended illumination values

for many locations in the home and the British Standard Code of Practice[3] has endeavoured to lay down basic requirements in terms of the size of lamp for different types and sizes of rooms. The latest contribution, and one which is likely to lead to valuable results, is Waldram's paper[4], which was presented to the Society in January, 1954, and described a simple method of designing a lighting installation from a specification of the required apparent brightnesses of the various lighted surfaces.

The lighting engineer is generally familiar with these recommendations, but it must be said that the majority of new homes are in the hands of architects, many of whom are still unwilling to seek or to accept the advice of the lighting profession. In the home, at least, the desirable partnership between architect and lighting engineer, which the Society has urged for so long, is still not close enough. Much more should be done to ensure that each profession understands the other's approach to this particular problem.

If, however, an attempt is made to apply the principles of good lighting to domestic interiors, so much latitude must be allowed for the vagaries of personal taste that often many of the principles must be abandoned. The question has been asked in the past whether this Society should even try to make its ideals of good lighting known to the public or, conversely, to assume that what a person likes is automatically good for him. The answer, in the authors' opinion, must be that if we are to adhere to our motto "Passim Spargere Lucem," then every means must be tried to present the case to the public.

The first object of a lighting engineer must be to decide what is the visual task which is to be lighted, and in the majority of rooms there are several answers to this question.

The modern trend of open planning in which large rooms are used for different purposes has increased the difficulty of answering this question as varying intensities will be needed in different places and at different times. For these reasons it is seldom possible to rely on general lighting only, and local lighting or localised general lighting must be the answer to quite a large number of the problems which lighting in the home poses. In the past it has been unusual to find homes where the electrical installation was suitable for this solution to be carried out effectively, as the idea of one central ceiling point with perhaps one lighting socket outlet was the only one which the majority of housing authorities could understand. Any householder who endeavoured to carry out a satisfactory lighting scheme with these basic provisions quickly found himself involved in temporary extensions to the permanent wiring system which were not conducive to either electrical safety or pleasing appearance. The British Standard Code of Practice on the Provision of Artificial Lighting published in 1945[3] recommended three lighting sockets in a living-room, and it is interesting to note that this seems to have had some influence on some local authorities who are now specifying socket outlets in accordance with the provisions of the Code. This is certainly a step in the right direction. The provision of an adequate number of socket outlets is so important that it is regrettable that last year there was a recommendation by a Government appointed committee[5] that there should be a reduction in the number of outlets in the electrical installation of new houses and flats.

Assuming, therefore, that local or localised general lighting are accepted as the methods most suitable for the home, the following points must be considered: (i) Positions in the room where increased illumination is required; (ii) Size, shape and structural features of the room; (iii) Decoration of the room.

The positions where a high illumination is necessary are known in most rooms. For example, in the bedroom the bedhead and the dressing-table are the most important positions, whilst the dining-table and the serving table in the dining-room need local lighting. The positions requiring high illumination in the living-room are more difficult to define. Thus, while it would be reasonable to provide localised general lighting

from fixed positions in the former rooms, the living-room should be lighted with portable fittings. The kitchen also lends itself to a system of localised general lighting with higher illumination at the sink, working table and the oven. Finally, those potential danger points, the stairs, must be given careful treatment to ensure that risers and treads can be readily distinguished. The size, shape and structural features of a room have an effect on the lighting design, and in particular the present trend towards low ceiling heights restricts the widespread use of pendant fittings or indirect lighting.

The decoration of the room has little effect on the planning of the lighting scheme where it does not involve general lighting, but may determine absolutely the appearance of the fittings, or the material for the shades.

It would be impossible in a general paper of this nature to try to lay down any specific treatments for all the various rooms in the home, but there are certain points which should be discussed. For example, the atmosphere of comfort and relaxation in the living-room can be enhanced considerably by lighting with standard lamps only. Floor standards will provide light on the ceiling and on the upper parts of the walls to create a general room brightness and avoid undue contrast between the visual task, lighted by table standards, and its background. The flexibility of such an installation is great, and the whole appearance of the room can be altered by changing the positions of the standards, and by using only certain of them its brightness pattern can be varied. The shades used on these standards should be regarded as expendable items to be changed periodically to harmonise or contrast with the other furnishings.

The use of indirect cornice lighting has a great appeal at first sight, but on further investigation there are a number of disadvantages in its use. It is naturally less efficient than direct or general types of lighting and is apt to give a rather uninteresting and depressing appearance to the room unless supplemented by additional and more direct forms of lighting. Its effective use also depends on maintaining a sufficient distance between the cornice and the ceiling which is impossible with the present trend towards reduced ceiling heights which has already been mentioned.

Another feature which is worthy of consideration is a domestic dimming switch by means of which the illumination in a room could be varied from full value to complete darkness. Such a switch would need to be designed on the variable transformer or variable impedance principle and its value for controlling all or a group of lamps in any room can be readily appreciated.

(5) Fluorescent Lighting

More than 99 per cent. of the homes in this country are without any fluorescent lighting whatsoever, while the number lighted entirely by fluorescent lamps is insignificant. As this form of lighting has become well established for other applications there must be very strong reasons why it has so far not become commonplace in the home. Discussions on this subject with people in many walks of life seem to indicate that there are five reasons why they have not installed fluorescent lighting and do not intend to do so in present circumstances.

These are: (i) Colour rendering and colour appearance of lamp; (ii) Starting difficulties; (iii) Choke noise; (iv) Cost; (v) Lack of suitable fittings.

Many of these are interrelated but an attempt should be made to discover whether there are any means of overcoming the causes of the complaints and making the introduction of fluorescent lighting into the home a more simple matter.

(5.1) Colour

The distortion of the colour of objects seen under fluorescent lighting has been one of the greatest obstacles to its use in homes. The distortion under filament lighting,

however, has been accepted without comment due to the fact that it was an accustomed distortion. To introduce fluorescent lighting into the home, the colour appearance and colour rendering properties of the lamps must approach closely to those of the filament lamp, and this fact now seems to have been realised by the lamp technicians who have evolved the " Deluxe Warm White " lamp.

The relatively low efficiency of this lamp is of little moment if it overcomes the colour difficulties, but sufficient experience is not yet available to enable any assessment of its value to be made. Having thus perhaps obtained a lamp whose colour characteristics are satisfactory, it should be possible to introduce improvements in efficiency with slight colour alterations which, if introduced gradually, would almost certainly be accepted without comment.

There is a school of thought which maintains that the first object should be to introduce fluorescent lighting into the kitchen and then let its use spread gradually throughout the rest of the house. This leads to such differences in colour rendering and illumination values between the different rooms that it is probably the largest single cause of the reversion to filament lighting.

Any attempt to capture the domestic market for fluorescent lighting is doomed to failure unless costs are such that the whole house can be dealt with in the same manner.

(5.2) Starting Difficulties

The delay in starting with a thermal starter, the flashing with a glow starter and even the slight delay with a transformer start are still great drawbacks to the use of fluorescent lighting. The circuit engineers must produce an instant start circuit which is as instantaneous as the filament lamp, before much progress can be made in the domestic field.

(5.3) Choke Noise

Despite the radio and television, there are still some homes where the occupants enjoy sitting quietly reading or talking and under such low ambient noise levels the inevitable hum of chokes or transformers can be most disturbing. It is realised that great improvements have been made in control gear design since 1940, but the noise should be reduced still more or, preferably, the source of noise should be eliminated completely from the fluorescent lamp circuit.

(5.4) Cost

There is not the slightest doubt that the greatest deterrent to the spread of domestic fluorescent lighting is initial cost. The average householder is prepared to spend perhaps £5 on a lighting fitting for the main room of the house and proportionately less for other rooms. With present-day prices the figure he must pay for a reasonable fluorescent fitting is probably nearer £20. Is it strange, therefore, that bearing in mind the few advantages of this form of lighting, he still buys a tungsten lighting fitting? The difficulties of any great price reductions are well appreciated, but if fluorescent lighting is to be brought into the home, then ways and means must be found of reducing initial costs.

(5.5) Fittings

The design of an attractive fitting for a fluorescent lamp is not an easy problem. Obviously, with the other deterrents to domestic fluorescent lighting, the design of home lighting fittings has not been tackled seriously and there is no doubt that given the necessary incentive in possible sales, attractive fittings could be produced. In view of the size of the average room, however, nothing larger than a 3-ft. lamp could be handled satisfactorily.

The circular lamp has distinct possibilities for more attractive fittings design.

Unfortunately, the advantages are off-set by the same adverse factors as have already been noted for the tubular lamp.

(5.6) Other Factors

There are two other factors which must be considered, although not generally put forward as obstacles to fluorescent lighting. All radio interference must be adequately suppressed and the number of circuit components, particularly the expendable ones, must be reduced to the absolute minimum.

(5.7) Summary

To sum up the above, the domestic fluorescent market requires :—

(i) A short lamp whose colour rendering and colour appearance is nearer to that of the tungsten filament lamp.

(ii) A real instant start circuit without chokes or transformers, with the minimum of component parts and adequately suppressed against radio interference.

(iii) Attractive fittings of all types, i.e., ceiling, pendant, table and floor standards.

(iv) Selling prices which must be greatly below those in force at present.

The introduction of the ballast lamp circuit has given hope that some of these problems can be overcome by its use. The mixture of fluorescent and filament lamps results in an improved colour rendering, it is of the instant start type and its initial costs are appreciably below those of the earlier circuits. If the principles of this circuit could be extended to shorter lamps and costs still further reduced, then perhaps domestic fluorescent lighting would become a practical proposition.

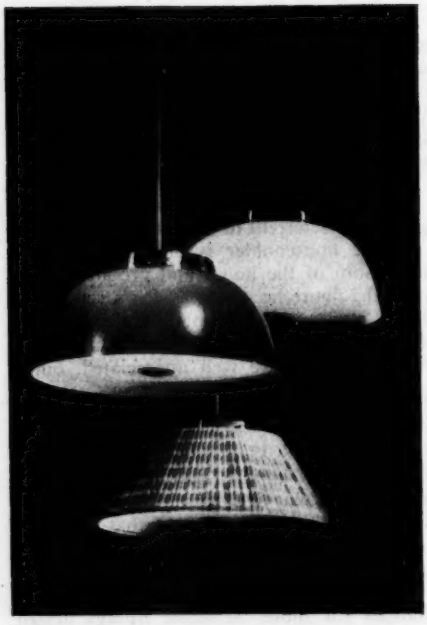


Fig 11. Three modern Swedish fittings.

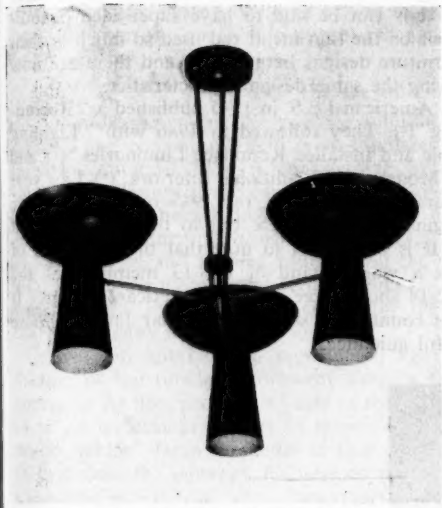
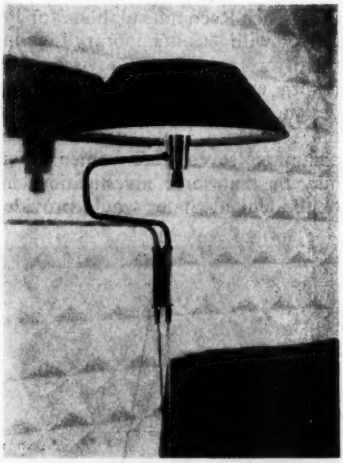


Fig. 12. A modern American fitting

Fig. 13. American adjustable wall bracket.



(6) Continental and American Practice

Comparing the current practice in this country with that in Europe and America, it is evident that we do not come out too badly in the amount of light used for domestic purposes. In general, it is possible to say that we have more light in homes in this country than any other country in Europe. Every country has its national characteristics, and, as one might expect, lighting fittings in the French home are very much more decorative than those we use here. Generally, however, there is nothing like the choice of reasonably designed fittings at economic prices that there are in this country.

In Western Germany great strides have been made in the last few years and many advanced designs are now being manufactured to suit the essentially contemporary architecture of their newly built homes. Great use is made of their extensive glass industry and some beautiful and delicate decorated glass shapes are now to be seen. It is a great pity that the glass industry in this country is not able to produce this type of lighting glassware at a price which would enable fittings manufacturers to use it extensively on standard ranges of fittings.

The Scandinavian countries have, for a long time, been leaders in the design of furniture and lighting fittings. Their influence can be seen to-day in this country and also in America with the many shapes of metal reflectors now seen on lighting fittings in many homes. One characteristic of Scandinavian lighting practice is their use of portable pendants and bracket fittings with free hanging flexibles. These fittings are moved about the room and hung on unobtrusive hooks on the walls or ceilings to ensure the light is obtained where it is required at any particular time. Three modern Swedish fittings are shown in Fig. 11.

The influence of Italy with her age-long reputation for fine design in the arts

and in industry has spread rapidly throughout the world during the last two or three years. As far as lighting is concerned Italy can be said to have superseded Scandinavia as leaders in this field. The emphasis on the thin metal rod used so much in their current designs can be seen in many furniture designs here to-day, and there are now a few examples of lighting fittings showing the same design characteristics.

In the United States of America the American I.E.S. in 1945 published a "Recommended Practice for Residence Lighting"(6). They followed in 1946 with "Lighting Preference Recommendations for Portable and Installed Residence Luminaries"(7), and in 1950 with "Contemporary Lighting in Modern and Traditional Interiors"(8). Last year there was published a revised and enlarged treatment of the 1945 report(9). These reports are directed not only to the engineers in the I.E.S. but to the architects and designers of interiors and equipment. It is of interest to note that the chairman of the Residence Lighting Committee was a woman, and of the 13 members of the committee seven were women. Figs. 12-14 show three modern American fittings. It may be that some investigations in this country on somewhat similar lines to those of the United States would provide useful guidance.

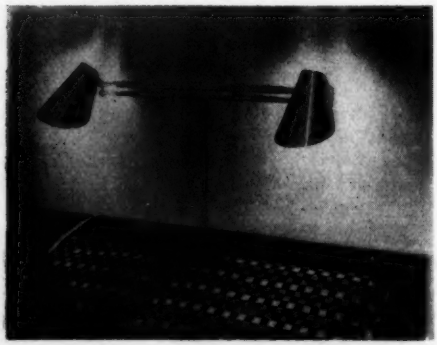


Fig. 14. American bed light.

(7) Electrical Safety

With the greater use of floor standards and table lamps it is more than ever important that careful attention is given to the design and manufacture of these fittings to ensure that they are safe to handle by both old and young. With portable lighting fittings the danger of trailing flexes is ever present and the use of adequate and well protected flexibles cannot be too strongly recommended. To-day the cable industry has a wide range of rubber and P.V.C. flexibles in many colours which withstand the hard wear to which these lamps are normally put.

Another factor which is often the cause of trouble is the lack of bushed holes for wiring entries. This would seem to most people to be an absolute necessity to prevent chafing of the flexibles, but table lamps and floor standards are still being sold without these elementary safeguards.

How many metal table lamps and floor standards have an earthing terminal and a three-core flexible in accordance with I.E.E. Regulations? Unfortunately, very few of those which reach the public. Just because it is a table lamp taking a 60-watt lamp, the average user thinks the chance of accident is much less than for power consuming equipment, which he treats with respect. Apart from the duty of the manufacturer who makes them, the retail stores and shops should not purchase such equipment to sell to the public.

Steps have been taken to set up a testing house in the electrical industry, but so

far no mention has been made of any lighting fittings being approved. It does appear that the existing system could be extended and publicised so that the public will look for the approval mark to ensure buying properly designed and made lighting equipment.

(8) The Future of Domestic Lighting

Any discussion on the possible future of lighting in the home is likely to be difficult and contentious as it is so intimately bound up with personal taste. Other factors also must have a considerable influence on developments. The general standard of living in the country will, to some extent, determine what proportion of his income the householder is prepared to use for lighting his home. The relative economics of different forms of lighting will, to a large extent, determine his choice of light source and lighting fittings, and the cost of electrical energy will have a big influence on the illumination values adopted. In addition to all these unknown factors, there remains the freedom of choice for the individual in accordance with his own character. May it always be so.

Are there any new developments in light sources in the offing, such as the introduction of the tubular fluorescent lamp in this country in 1940? There would not appear to be any prospect of this in the foreseeable future. However, there is likely to be an increase in the use of fluorescent lighting in the home. The new "Deluxe Warm White" lamp marketed in this country in March, 1954, is a further attempt to overcome the inherent difficulty of providing a good colour appearance for social surroundings. It will need, however, the other considerable changes discussed in Section 5 before the fluorescent lamp will take the place of the tungsten lamp for domestic use.

In recent years research work on electroluminescence has been undertaken in laboratories, but so far indications are that nothing can be expected commercially for many years—if at all. In spite of this, electroluminescence is now being used commercially in this country for industrial applications. Its application to the lighting field can readily be visualised when at the touch of a switch the ceiling or walls of a room can be made to emit light.

The lighting engineer cannot be expected to have such an appreciation of the aesthetic problems of lighting as the architect or designer, and it is nearly always proved that the most successful lighting schemes are those where there has been co-operation between the engineer and the architect. This was emphasised by the assessors of the first Dow Prize Competition, sponsored by this Society. It does seem that continued attention should be given to encouraging architects and others interested in the problems of lighting, to join and take part in the discussions of the Society. This is apparently happening in other countries, and only recently an architect has been President of the Illuminating Engineering Society of Australia. It needs this closer interchange of information and ideas if we are to solve our lighting problems successfully.

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Discussion

MR. E. S. EVANS: I congratulate the authors for their courage in presenting a paper on the very difficult problem of domestic lighting. In common with the majority of lighting engineers, I am always seriously concerned when friends or business acquaintances ask me how they should light their homes, because I have not even found an answer to lighting my own home. The authors have given an excellent review of the fundamentals of domestic lighting which will create ideas for the lighting of the home and the development of the market. Although I am not an admirer of modern contemporary design and favour the more traditional or period design, I have no doubt that there is a place in the home for modern styles of furnishing and lighting.

The majority of homes in this country are still using lighting which was designed for the old carbon and metal filament lamps; even to-day there are many thousands of eight-inch and 10-inch opal shades sold in this country, and many of them are fitted into new home-lighting installations.

The problem of educating the public in the best methods of lighting is extremely difficult, and I well remember the "Wiring-in-Britain" campaign in 1928, the Lighting Service Bureau, E.A.W. and other campaigns for home lighting. Various organisations have constantly publicised methods of good home lighting, not without some success but still leaving the majority of homes badly lighted.

It is difficult to lay down definite methods of home lighting because people's likes are a matter of individual taste, depending on the type of furnishing and general ideas of decoration, but it should be possible for the industry to produce a code of home lighting.

The question of fluorescent lighting in the home is naturally causing considerable concern to manufacturers, but it appears that the majority of householders are satisfied that fluorescent lighting is good for the kitchen, bathroom and garage, but have mixed opinions about its use in other rooms in the home. The reason for these mixed feelings is that frequently exposed fluorescent lamps have been used, but where the lamps are concealed the lighting effects are approved. No doubt the new fluorescent lamp colours will improve the general opinion of fluorescent lighting, but methods of installation must be carefully considered.

MR. D. W. DURRANT: In domestic lighting it must be remembered that fittings are seen unlit for far longer than they are seen lit; in the home they are used for decoration in the same way as pottery, plants or paintings are used.

We cannot fall back on that somewhat threadbare cliché that the satisfactory solution to this is co-operation between the architect and the illuminating engineer, for in domestic lighting there just is no architect; we are the people who are called upon to advise, and no lighting man worth his salt should shelter behind somebody else's cloak. I think personally he must be fundamentally an artist rather than an engineer, as, generally speaking, an artist can be taught the technicalities, but artistic ability either is there or is not.

I was a little sorry that the paper did not deal with the subject of the external finishes and shapes of fittings; for example, the use of dominant reds as opposed to subdued greens and blues. This introduction of strong colours into domestic interiors is on the ascendant, and I think we are getting very much more pleasant and cheerful environments in which to live as a result of that. Our job is virtually to paint a pleasant interior picture by day and by night, although, of course, the foci will be different.

I agree with the authors that flexibility in home lighting is essential, but I doubt whether gadgets and means of adjustment on fittings are really the solution, because in my experience once fittings are installed they are very rarely adjusted. I also

deprecate the point of view which advocates the abolition of points on the ceiling. Why should a ceiling be a flat, white, uninteresting slab? It must also be remembered that so often one needs the convenience of a switch near the door to give you immediate general lighting.

On the question of fluorescent lighting, the authors suggest that chokes have to be silent, but in this world nothing is silent : it is all relative. Will the authors state what noise level they feel would be acceptable and by what method it should be measured? I feel that fluorescent lighting is eminently suitable for the kitchen, simply because it fits. There is a statement in the printed paper which implies that a lot of people who have tried it only in this room discarded it. That is not my experience and I would be interested to learn the experience of others on this question.

Regarding the future of domestic lighting, I agree that the popular magazines, especially those primarily for women, are doing us a very sound service, especially when they portray the complete interior in colour.

Regarding Continental practice, I think the main difference between here and abroad is that, generally speaking, lighting fittings abroad are an accepted item of the furnishing budget. We are a very long way behind that, and I should be happy to think that the authors' statement was true—that a normal householder is likely to spend £5 on the lighting fittings for the main room. I should have said that 10s. 6d. would be nearer the mark!

MR. E. B. SAWYER : It is not perhaps generally realised that the fatal accidents in the home exceed in number those on the roads. A great many of them are due to people falling downstairs and the majority of the total are due to people not seeing. That really imposes upon us the very grave responsibility of doing all in our power to ensure that the new houses which are being built at the rate of 1,000 a day shall be so wired and so lit that the likelihood of accidents will be reduced to a minimum. It is the ball left on the dark stairs, the hidden flex from a boiling kettle that causes these bad accidents.

It is unfortunate that quite recently in a publication entitled "The Quicker Completion of House Interiors," a section therein said that the electrical installation should be reduced to the minimum; that, to me, is not a satisfactory state of affairs, bearing in mind the problem with which we are faced.

We also have to realise that there are thousands of houses in this country in which the occupants have to work in their kitchens by artificial light whatever the time of day because the daylight factor is too low for adequate vision. The survey revealed a very sad state of affairs in home lighting generally. There has been no substantial improvement since the war, for it is known that a great many people take a lamp from one room to another so that they can have light.

Finally, with regard to fluorescent lighting, my own view is somewhat opposed to that of the authors. I feel that fluorescent lighting has a place in the kitchen, it is acceptable there and does not really stop its use in other parts of the home, especially when built-in for decorative purposes such as behind pelmets and in alcoves—a section of home lighting which is not fully dealt with in the paper.

MR. A. G. PENNY : I want to make two comments. Mr. Sawyer referred to the electrical danger of the flex from the kettle, but I think the physical dangers of the flex from the floor standard and the table standard are much more serious.

There are in the home too many hazards already—too many things over which people fall. Falls are a major cause of accidents in the home and we should give as much attention to preventing falls as we do to preventing electrical shock. There should be no such thing in the home as long, trailing flexes.

The other point I wanted to make was on this question of the necessity for

instant starting with fluorescent lighting and the objections to the interval of a second or two between switching on the light and the light appearing. In this age of cheap and abundant electricity, I really cannot see the point of turning off the lamps during the course of a few hours in the evening. When it gets dark, turn on the lights and turn them off when you go to bed, but why bother in the meantime to try to save a few farthings by switching them off whenever you leave the room?

DR. H. H. BALLIN: It is very welcome to note that since completing the written version of their paper, the authors have slightly changed their attitude towards fluorescent lighting. If I understand rightly the conclusion reached by Mr. Young, he feels that there is an increasing use of fluorescent lighting in the home—a statement which I cannot trace in the paper. This is indeed very encouraging to those of us who have a slight bias towards fluorescent lighting as the modern source of lighting which will find its application in the home.

I would like to suggest one or two reasons why fluorescent lighting has not been more widely adopted for home lighting. First of all, economics, which are a determining factor in industry, are not so important in the home. Secondly, the fact that in the home lighting is a matter of taste, and individual ideas necessitate a much wider variety of designs. In the years since the war there just has not been the time for designers to get down to this problem. The experience of some electricity boards who have sponsored campaigns advertising fluorescent lighting for houses, coupled with the success of some of the few domestic lighting fittings which have been put on the market, seem to indicate that there is a wider field for this form of lighting than we may at present envisage.

I would like to refer to the most attractive illustration in the earlier paper by M. Claude, showing a glass chandelier which provides little light but looks most delightful, the room itself being lit by fluorescent lamps. In built-in lighting, for modern buildings in particular, I think there is tremendous scope for fluorescent lighting in alcoves, for false ceilings, false windows, Venetian blinds and such like. It is also conceivable that, with some ingenuity, lighting engineers may devise features which can be installed in a house after it has been completed.

I think in this field further progress will be made and that all the slight objections which Mr. Young has mentioned, and which are very real ones, will be overcome.

DR. W. J. WELLWOOD FERGUSON: May I speak as a person who would like to have his house lighting very much improved? I hope my comments may stimulate some of the ladies to add theirs. One of the chief obstacles to this desired improvement is the fact that major alterations require considerable work by builders and decorators, first of all to effect, and then to conceal the alterations. Short of these drastic measures it is very difficult to improve the lighting unless the house is, as Mr. Penny puts it, festooned with flexes.

MR. C. HUGHES: I am not sure that it is the lighting engineer's prerogative to interfere in a field of practice so close to fashion. I do not think that any man would dare to interfere in the realm of ladies' fashions and I think decorative lighting in the home is analogous to that.

Over the years, we have seen the change from the Victorian petticoat which used to surround lighting equipment to what I may perhaps call the Elizabethan briefs!

Home lighting is a matter of individual taste; it is the artistic end of the problem. I think the lighting engineer's function is to educate lighting fitting designers to so design their fittings that they are both attractive and efficient.

There is some conflict between the metal manufacturing side of the lighting fittings industry and the glass or plastic side of it. We have seen phases in years past where

perhaps the glass people have been predominant and there has been very little metal work; then you have the converse where the fitting has been almost all metal and very little glass. Those are conflicting interests and I think that here also it is the function of the lighting engineer to give guidance.

MRS. J. G. HOLMES: We have been told quite a lot about what we should not do in lighting our homes and I think we should ask a direct question about what we should do. I am the wife of a lighting expert, I believe. We have excellent lighting in the kitchen, the lounge, dining-room and bedrooms, but I would like to ask the authors' advice on the best way to light a staircase not only for safety but always bearing in mind that one of the best ways for a hostess to receive her guests is as she descends the stairs. At the moment I cannot ask my husband because we live in a flat!

MRS. E. B. SAWYER: Having listened to Dr. Aldington's paper earlier this week, when we saw the marvellous advances which have been made in producing light and then seeing these slides this afternoon, I feel that it is the designers who really are important now, in that the fittings are not up to the high standard of the lamps available.

Mr. Evans said that he preferred the old-fashioned type of shades and, really, I am not surprised. I do not mean I am not surprised after seeing the fittings we are expected to buy to-day compared with Victorian and pre-war fittings, but I mean that we still prefer the lovely antiques.

I think that if I were going to have a new house built now, I should be very tempted to say, after seeing these fittings: "Could we have all concealed lighting?" It would accompish two things: it would give my husband the job of attending to it and I would have nothing to clean and then, if anything came along which was worthwhile later on, we could always add it.

MR. M. BASKEYFIELD: A previous paper has amply displayed the need for lighting engineers who are essentially artists; this paper has endorsed this need. It is evident that Mr. Young is an artist very much concerned with his own work and I am sure we industrial lighting engineers have found the paper most refreshing.

However, contrary to what the authors say, I believe the aesthetic problems of lighting can largely be solved by the artist-lighting engineer, and not by the architect. The latter must generally accept what the manufacturer provides, and will always do so if it has appeal. In addition, we are not altogether concerned with major structural alterations to domestic interiors or carefully planned considerations for lighting prior to building. We want everyone to be light conscious; we want the present millions of householders to learn the rudiments of good lighting, to appreciate its value, not only because it provides good seeing conditions, but because of its very wide decorative value. We want everyone to appreciate the art of domestic lighting as they would the art of arranging a bowl of flowers.

The average householder's imagination goes very little beyond a flex dangling from the centre of the ceiling and a lamp on the end of it. He knows nothing about angles of cut-off, lamp burning positions, etc. I notice that one lamp manufacturer now publishes a leaflet on home lighting; they are to be congratulated. Manufacturers should concentrate on this enormous potential, and sell home lighting to the public in the same way as refrigeration.

I observe there is a trend to get away from the commonplace pendant light and that there is now a greater use of standard and table lamps. A little imagination goes a long way and I am sure there is a splendid future for the well-designed portable type of decorative fitting with which the householder can so readily transform the domestic interior.

There has been some discussion on the point of trailing flexes. These only occur

where there are an inadequate number of sockets in the room and I am pleased Mr. Young has referred to the recommended number. In my own dining-room there are four sockets, one to each corner, each feeding a table lamp. This arrangement provides a restfully illuminated interior, a minimum of glare and easy method of changing the scheme at will, including dimming effects.

DR. R. HALLE (written contribution): Those of us engaged exclusively in the manufacture of lighting glassware, must take seriously—and, in fact, regard as a challenge—the authors' statement that lack of new developments from glass manufactures, coupled with the high price of contemporary designs, are at least partly responsible for glass not being used in this country so extensively for the more decorative types of fittings.

At the same time, it may be permissible to point out that successful designs are generally the result of close co-operation between the designer of the fitting on the one hand and the manufacturer of the component parts on the other. Such collaboration, which happily exists in many instances, is essential in bringing home to the manufacturer what is aimed at and to the designer what is practicable.

MR. S. ANDERSON (written contribution): While the authors may be writing from personal experience in their criticisms of starting delay and choke noise in Sections 5.2 and 5.3, I feel it should be recorded that well-designed and correctly installed "instant start" control gear is capable of starting the fluorescent lamp within a fraction of a second, and I cannot believe that a delay time of this order is a handicap in popularising fluorescent lighting in the home.

Similarly, some control gear is made with a noise level at 1 in. not exceeding 25 db. above the threshold of audibility under specified test conditions. Such control gear is inaudibile from a distance of 3 ft. or more even in the quietest obtainable surroundings, provided that the fitting in which it is mounted does not amplify or add to the sound. With a little care it is thus quite possible to achieve a "silent" fitting for the home.

THE AUTHORS (in reply): The discussion has underlined two of the points made at the start of the paper; firstly, that any other person speaking on the same subject would have dealt with it in an entirely different way, and secondly, that the subject of home lighting is predominantly one of personal taste. Many speakers have given their own ideas, some agreeing with us and some disagreeing, but we would never presume to tell any of the speakers that their ideas are wrong merely because they differ from our own. Many speakers have touched on the point made in the paper that individual taste must play a very large part in home lighting; Mr. Evans, Dr. Ballin and Mrs. Sawyer have all taken up this theme and Mr. Hughes has gone so far as to doubt whether the lighting engineers should even interfere in this particular field. Mr. Evans also mentioned the problem of educating the public on the best methods of lighting and the authors feel that taking a long term view, the best method of education is to enable the public to see well-designed lighting installations and well-designed lighting fittings. The remarks made by Mr. Hughes are also relevant here, namely that liaison between the lighting engineer and the designer must take place at an early stage so that well-designed fittings are also efficient fittings.

Several speakers have referred to the subject of fluorescent lighting for the home, but have not, in our opinion, given the answer to the criticisms made in the paper. The idea of attempting to light the kitchen by means of fluorescent lighting in the hope that the new system will spread throughout the house is, in our opinion, unlikely to be successful, owing to the fact that the other parts of the house are left with ordinary lighting and the constrasts of illumination levels and colour rendering between

the various rooms are most apparent and most disturbing. Blame is then likely to be placed on the fluorescent lighting with most unfortunate results.

Those who have been able to light a complete house with fluorescent lighting, thereby suffering no violent contrasts in colour rendering and illumination values in going from room to room, have accepted the new light source much more readily than those who have experimented only in one room.

Mr. Durrant and Mr. Anderson have spoken on the noise from control gear. We appreciate the difficulty of maintaining a low noise level and also the inherent difficulties of specifying and measuring that level. What is required, however, is control equipment which would be inaudible at the low ambient noise levels experienced when the occupant of a room is sitting quietly reading without the additional noise of radio or television. Such an accomplishment should not be beyond the capabilities of the transformer engineers.

Mr. Anderson has also raised the point of the starting delay and that matter has also been mentioned by Mr. Penny. Whilst appreciating that with instant start control gear the delay is only of the order of a fraction of a second, there is still the psychological effect of having to pause at the entrance to a room before the lamp strikes. Apart from all statements to the contrary, we believe that even this small delay is the cause of some of the opposition to fluorescent lighting in the home.

There is no doubt, however, that the most important obstacle to the wider use of fluorescent lighting in the domestic market is cost, and although the figure of £5 was mentioned in the written paper as the amount which a householder may spend for the lighting fitting in the main room, Mr. Durrant has put this figure at 10s. 6d. If his figure is nearer than ours to the true state of affairs, then the future of domestic fluorescent lighting is far more uncertain than we have stated! We agree with Mr. Durrant that it is a pity that other aspects of the subject of home lighting could not be included in the paper, but in its preparation we reached the stage when it was extremely difficult to decide which part of the subject to omit.

The question of shapes and external finishes of fittings could easily occupy another full session of the conference and we suggest that perhaps other members might present a further paper to the Society in due course.

On the subject of flexibility of lighting, about which both Mr. Durrant and Mr. Penny have spoken, the solution to the dangers which were mentioned is undoubtedly a greater number of socket outlets in domestic premises. This has also been emphasised by Mr. Baskeyfield and although, as Mr. Sawyer remarked, the publication of the document entitled " The Quicker Completion of House Interiors " recommends the reduction of outlets to a minimum, we feel that there are signs of an improvement in the position.

Lighting cannot be fully flexible and safe unless adequate outlets are provided. The control of one socket outlet to a switch by the door would overcome Mr. Durrant's requirements for immediate general lighting.

Printed by
ARGUS PRESS, LTD.,
Temple-avenue and
Tudor - street,
London, E.C.4,
England.